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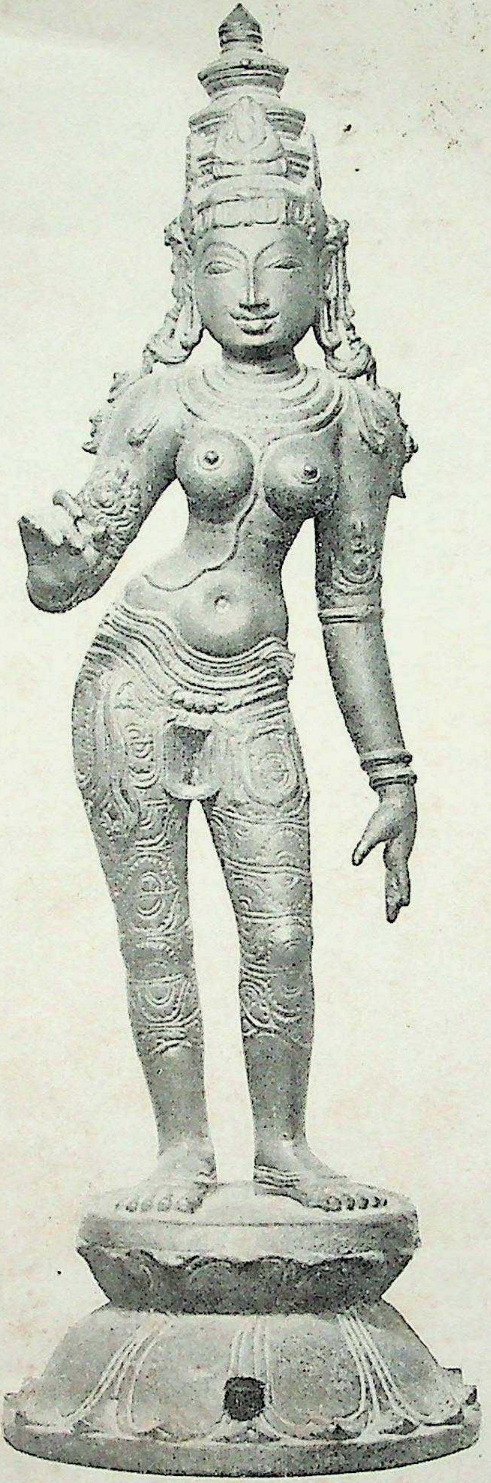

M. V. KRISHNAN

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CIRE PERDUE CASTING IN INDIA

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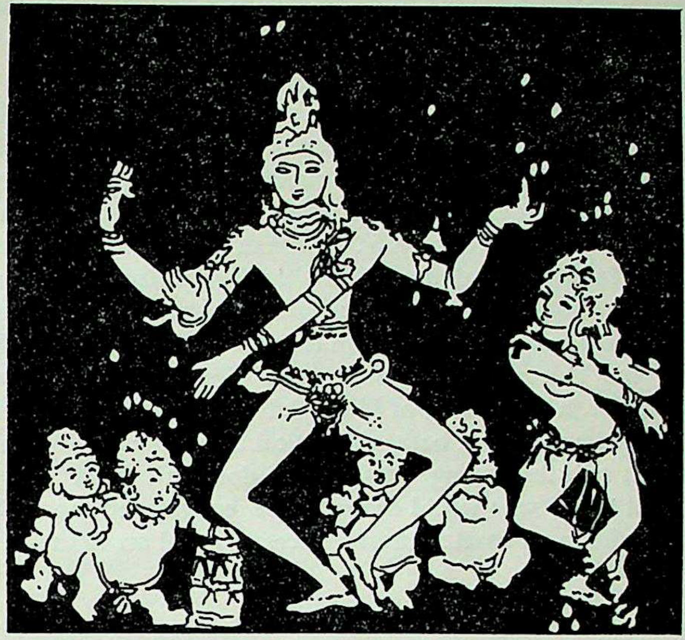
Sept. 16, 1976



सन्मार्गालोकनाय व्यपनयतु स वस्तामसीं वृत्तिमाशः

FOREWORD

Cire perdue or the lost wax method of casting images in metal has had a long history of tradition and growth. The earliest examples of this method have been unearthed in the excavations at Mohenjodaro. The famous metal miniature known as "the dancer" is not a lone image of that remote age that evokes wonder not only for its perfection as an art piece of exquisite elegance but also for the advanced knowledge of technique for its production nearly five thousand years ago. There are other and still more tiny metal pieces from Mohenjodaro and Harappa illustrating animals like the buffalo, bull and dog exquisitely moulded in wax with the details of anatomy bespeaking not only the highest artistic excellence in the sculptor who could make such a fine study individually of each one to perfection but also of his technical perfection in reproducing the finest details in an almost untouched cast image requiring little or no final finishing touches.

The method was used all over the sub-continent with an amalgum of metals ranging from five to eight in the solid or hollow method of casting as required by the size and purpose of the image. Though there are early references in literature and inscriptions mentioning both the methods and the process itself, it is the *Manasollasa* or *Abhilashitarthachintamani*, an encyclopaedic work by the Western Chalukya King Somesvara Bhulokamalla of the twelfth century, that gives an elaborate description of the process.

The perfection of casting images in India was reached in the Gupta-Vakataka and early medieval periods when some of the finest examples like the Sultanganj Buddha, the Pophnar Buddhas, the Brahma from Karachi, the Jain images of the Akota hoard, the Nalanda and Kurkihar bronzes, and the famous Pallava and Chola bronzes of South India were prepared.

Not only classical examples but numerous others in folk style were produced in this mode of casting all over the country for ages and continue to be prepared even today. As a sculptor Dr. M.V. Krishnan was naturally interested in a study of the traditional Indian techniques of *cire perdue* casting in their relation to those of other parts of the ancient world and the latest modern Western techniques. He has made a fruitful study which is a contribution to our knowledge in this field and it has earned him the Doctorate of the Banaras Hindu University where he has been teaching sculpture in the Faculty of Music & Fine Arts for several years. He has brought his knowlege and experienee, both theoretical and practical, to enliven a theme that is as important as is fascinating. I have no doubt his book will be welcomed and studied by all those who would desire to be enlightened on a technique that has given some of the most coveted masterpieces of metal art in the word.

New Delhi
16th September, 1976

(C. SIVARAMAMURTI)

PREFACE

As a sculptor I have been keenly interested in the study of the traditional Indian and modern western techniques in *cire perdue* casting. Although much had been said about the glory of the ancient Indian bronze cast by this process, no serious attempt has been made to make a critical study of the traditional techniques of the past as well as of the present. Today the traditional Indian craftsmen in this art are facing great economic distress due to dwindling of their traditional patrons. Dire poverty often drives some of them to take up other vocations of profit. This might result in the extinction of this traditional art. Such a situation prompted me to take up a comparative study of *cire perdue* casting process, traditional and contemporary, with a view to find out how our traditional craftsmen could be benefited by incorporating modern methods. Any positive result in these lines might go a long way in preserving our indigenous tradition. The major portion of the work so far as the technical side is concerned, is based on my own investigation. For textual material I have received important light from the text of the *Mānasollāsa* that was published by Professor S.K. Saraswati in the Journal of the Indian Society of Oriental Art, Vol. IV, 1936 and I have supplemented this by relevant extracts from two other texts, the *Śilparatna* and the *Mānasāra*.

In Chapter I has been abstracts of the important technical information from the three ancient Indian texts, *Mānasollāsa* (12th century A.D.), *Śilparatna* (16th century A.D.) and *Mānasāra* (of unknown date) provided. The *Mānasāra* is still used as a practical guide by the *Sthapathis* of South India. In Chapter II, the techniques preserved by the *Sthapathis* of Swamimalai, who are considered to be the best craftsmen in India, have been studied and their methods and materials are compared with those in the other parts of the country. In Chapter III, a critical analysis of the techniques described in the texts and those still used by our craftsmen is attempted. This shows how far the techniques mentioned in the texts compare with the existing ones. Chapter IV deals with the technique of *cire perdue* casting practised in Nepal, Tibet, Ceylon, Burma, Thailand, Indo-china and Indonesia. In this, the method used in Nepal has been described in detail. The methods used in these countries have affinities to those found among our craftsmen and obviously seem to have reached these regions, along with the spread of Indian civilisation. In Chapter V, the techniques used during the Shang period in ancient China and the traditional techniques found among the Japanese craftsmen are described by way of comparison to other traditional techniques. Chapter VI is devoted to a brief study of the techniques used by the craftsmen in ancient Egypt, Mesopotamia, Greece, Rome, Peru (Incas), African Kingdoms of Benin, Yorubaland and Ife. The media and methods used by the craftsmen in these civilisations compare well the existing techniques of India. Chapter VII deals with the modern techniques of the West, since Renaissance up to the present time. In Chapter VIII, an analysis of the traditional techniques existing in India today and the contemporary methods of the West is attempted.

I am deeply indebted to Professor S.K. Saraswati, Head of the Department of History of Art, Faculty of Arts, Banaras Hindu University for suggesting the problem, guiding me with his enlightened discussions and for critically going through the manuscript. I am grateful to the University Grants Commission of India for the financial assistance which enabled me to visit the craft centres at Swamimalai (Tamil Nadu), Bronze production centres at Bangalore, Kumbakonam (Tamil Nadu) and Patan in Nepal. The financial assistance provided by the Banaras Hindu University and the U.G.C. of India to attend the Seventh National Sculpture Conference at the University of Kansas, U.S.A. in April 1972 has helped me to have a closer understanding of the contemporary problems in *cire perdue* casting. I am grateful to Professor Elden C. Tefft, Professor of Sculpture at the University of Kansas for his suggestions. My thanks are also due to Shri Kali Prasad Visvakarma, the traditional craftsman in the Department of Plastic Arts, Faculty of Music and Fine Arts, Banaras Hindu University, for his assistance throughout this study.

I am thankful to Dr. C. Sivaramamurti for contributing the Foreword. I am also thankful to the National Museum of India, New Delhi and the American Institute of Indian Studies, Varanasi for providing photograph for the cover design.

Lastly, I thank Sri Jayant Baxi for publishing this study.

M.V. Krishnan

October 1976
Varanasi, India

INTRODUCTION

It is difficult to say when and where the technique of *cire perdue* casting was first invented. In India it is known to have been in use nearly five thousand years back. The technique seems to have almost parallel developments in different areas of the old world. Its origin and progress are closely linked with the discovery and knowledge of the use of metal. Early man observed that metal possesses certain unique properties. He discovered that it is hard in natural state, ductile when heated, melts at a higher temperature and solidifies when cooled. Again two or more metals can be combined to form an alloy which is even harder than the parent metals. Thus he developed the technique of forging and casting for his use.

The technique of casting in metal requires a negative shape to obtain a positive. The negative shape can be prepared either by carving on a hard material or made out of a plastic medium over a positive form. The latter process requires the ability to prepare an original in a plastic or glyptic medium. The development of a plastic compound is necessary to withstand the high temperature reached by molten metal. All these involve an advance in technology. To begin with, the early man carved dugouts in stone for the negative form and filled it with molten metal and made simple one face solid castings. Next he developed suitable clay compound and prepared simple two piece moulds from an original for solid castings. He noticed that he could retain the contour of his castings and also save metal by introducing a lump of clay (core) and make hollow castings. The development of clay moulding technique ushered the invention of *cire perdue* (lost wax) technique of casting. Man now desired to cast complicated forms. This required new techniques in modelling and moulding. This can be done in three ways: by modelling solid forms in wax with provision to drain out the wax, moulding it in clay, melting out the wax and creating a negative form inside the mould, filling the cavity with molten metal and thus obtaining a cast. This technique is known as solid casting. The weight and expense of solid casting prohibit its use for large works. This led to the development of hollow casting. The idea of hollow casting seems to have been originated in two ways. It was found that it is possible to take moulds from a glyptic work by suspending a core form with core pins in between the moulds and by filling the interspace between the mould and the core with molten metal and obtain a hollow cast. The other technique is to shape a core form slightly smaller than the cast intended in metal and applying wax sheets equal to the intended thickness of the cast over the core form. The solid and hollow casting by modelling a wax original is known as the direct process of *cire perdue* casting. This procedure permits the sculptor to visualise his idea directly in wax, mould the original and obtain a cast. The technique involves the melting out of the wax original which explains the name to the technique. In this method only one casting is possible because the mould is destroyed to release the cast. It has one serious drawback because of the danger of losing the whole labour of the artist, if the casting is defective. This means enormous waste of time and energy in the case of large undertakings. So the development of a new technique became necessary to overcome these drawbacks. This led to the development of indirect process of *cire perdue* casting.

Though some form of indirect process of *cire perdue* casting was prevalent among the craftsmen in some ancient civilisations, a systematic use of it for sculpture casting came into use, since the Renaissance age in Italy. During this period the plaster piece-mould method for the indirect process was developed. With the advance of science and technology the plaster piece-mould was replaced by the flexible mould method, first by using gelatine and later with natural rubber and today with synthetic flexible moulding media. In the indirect process the original is generally in clay and a plaster copy of it is obtained through the waste mould process. A wax replica of the plaster copy is obtained for *cire perdue* casting with a plaster piece mould or by flexible mould. The indirect process enables the sculptor to guard himself against the danger of losing his original by conserving it in the negative form in the piece mould or flexible mould. It also permitted him to have a number of copies of his creation.

For centuries man has been depending upon beeswax as the principal modelling medium for *cire perdue* casting. In a warm climate it turns too soft and in a cold climate it turns too hard for working. In order to make it suitable for working in different climatic conditions the craftsmen in many areas mix rosin, oil, wool fat, and prepare compounds according to their needs. Today, industrial technology has produced the micro-crystalline wax which have been found to be more suitable for *cire perdue* casting. Micro-crystalline wax, a by-product of petroleum is marketed in forty different grades and can be used without the use of additives except for a colouring medium. Being an industrial by-product it is cheaper than beeswax. Foam plastic, a product of plastic industry, has enabled the contemporary sculptor to develop a new technique of metal casting in which the burn-out process is completely eliminated.

Similarly clay added with some organic materials has been the principal medium for moulding in *cire perdue* casting. During the Renaissance age plaster of Paris came to use. Today, technology has developed special casting plaster that can withstand temperature up to 1000° F. Many new products developed by industry now serve as binder for the plaster mould for *cire perdue* casting. Being industrial products they are marketed ready for use. In comparison to a clay mould a plaster mould takes less time to prepare. Hence the plaster mould has replaced the traditional clay mould for *cire perdue* casting.

With the advance of science and technology many new tools and techniques have been developed for various uses. The contemporary sculptor has adopted these tools to the best of his advantage. The evolutionary history of the media and methods used in *cire perdue* casting from early times in different parts of the world and a comparison of the existing tradition in India and in some areas of the world with the contemporary process are discussed at length in this thesis.

INDIAN TECHNIQUES AS DESCRIBED IN ANCIENT TEXTS

Our knowledge about the Indian tradition in the various technical aspects of *cire perdue* casting is derived from three ancient works in Sanskrit which deal with the step by step process that was followed by the ancient metal founders. These works are:

I. *Mānasollāsa* otherwise known as *Abhilasitārtha chintāmani*.
II. *Śilparatna*.
III. *Mānasāra*.

I. *MĀNASOLLĀSA*[1]

This work is so far the oldest which gives information on various practical aspects of *cire perdue* casting. It belongs to the twelfth century and its authorship is attributed to King Bhūlokamalla Somesvara of the western Chalukya dynasty of Kalyāni. This work deals with varieties of subjects. The descriptions of the technical aspects of *cire perdue* casting are more or less complete.

TECHNICAL PROCESS FOR PREPARING A METAL IMAGE

In prakarana I the *Mānasollāsa* describes the process of casting a solid image in metal. In twenty verses (verses 78 to 97) the author explains the various aspects of casting an image. The technique of casting by *cire perdue* process can be divided into four principal stages. They are:

A. *Modelling*: concerned with the preparation of a wax model.

B. *Moulding*: concerned with the preparation of a clay negative (mould) of the wax model for casting.

C. *Casting*: This can be subdivided into a number of successive processes such as: (a) ascertaining the ratio of different metals in proportion to the weight of the wax model; (b) draining out the wax from inside the mould (dewaxing); (c) melting process-temperature required for melting different metals; (d) casting process; (e) releasing the cast from the mould (devesting).

D. *Finishing:* concerned with the perfecting of a metal cast.

A. *Modelling*

"An expert should first prepare according to the *Nava tala* measurement a supple and smooth image, beautiful to look at, with all the limbs and *lakshaṇas* and with the weapons prescribed for the deity to be made" (verses 78, 79).

" A long rod in the shape of a *Kāsa** flower having a long stem is to be fixed either on the back or shoulders or neck or the crown" (verse 80). This is intended for the sprue.

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*Mysore edition has the reading *Hema-pushpā* which suits the context better. *Hema-pushpā* means *datūrā* flower and the shape exactly suits the purpose of a sprue.

B. *Moulding*

"Mix clay, charred rice husk, cotton severed hundred times and a small quantity of fine salt and ground them together to a smooth paste over a stone. Smear the image all over evenly with this clay, leaving out the mouth of the tube. Do it thrice. The first layer should be transparent (that is thin) and is to be dried in shade. After two days should be applied the second coating. When this is dry, should be applied the third coating in thick layer. An intelligent person should dry it as reason demands" (verses 81-85).

C. *Casting*

(a) The first problem with reference to casting is to ascertain the ratio of different metals to be used for casting. This is enjoined to be done in relation to the weight of the wax model (it is to be noted that the weighing of the wax model is to be done before the operation for moulding begins).

"In order to ascertain the amount of metal (brass, copper, silver or gold) required for casting, the wax that is used for modelling the image should be weighed first." The ratio of different metals are: Copper or brass eight times*, silver twelve times and gold sixteen times the weight of the wax (verses 86, 87).

Present-day craftsmen follow two methods. In the case of a solid wax model it is weighed after the modelling is finished. If it is a hollow model the core is weighed before modelling the wax over it. The wax model is weighed again after the modelling. The difference between the first and the second weighing shows the amount of wax used in modelling.

"Encase the required amount of the chosen metal (gold or other metals) in clay (crucible clay) and make the crucible in the shape of a cocoanut. Dry it as explained before (as stated for drying the mould)" (verse 88).

(b) With reference to the process of draining out the wax from inside the mould: "The wax of the model should be drained out by heating the mould in fire" (verse 89).

(c) With reference to the process of melting the metal and thet emperature required for melting different metals: "The crucible should be heated on burning embers. Brass and copper melt in mild embers, silver melts in flaming embers and gold melts in blazing embers, five times the normal heat" (verses 89-91).

(d) With reference to the casting technique: "A hole is to be punched on the top of the crucible with a sharp iron rod and with the help of tongs the heated crucible is to be taken out. A lighted wick is to be placed at the orifice left by the wax rod on the mould and liquefied metal is to be poured into the orifice of the mould in a continuous stream by tilting the crucible firmly with tongs till the mould is full to the brim. The operation is then stopped and the cinders around the mould are extinguished for cooling down (of the mould)" (verses 91-94).

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*Mysore edition mentions ten times the weight of the wax.

(e) With reference to the releasing of the cast from the mould: "After the mould is completely cool, the expert should break off the baked clay (of the mould) slowly and carefully. The metal image that comes out will be just the replica of the wax model in all its details" (verses 95, 96).

D. *Finishing*

"The superfluous attachments, such as the sprue, are to be removed by filing and the image chased and finished" (verse 97).

This work does not provide the following technical information on the subject. They are: (1) the composition of the wax used in modelling; (2) places from where moulding clay is procured; (3) different types of clay preparation used in *cire perdue* casting; (4) fuel used for heating the mould and the crucible; (5) method of making the kiln and baking the mould for casting; (6) method of making the furnace for melting the metal; (7) modelling tools, foundry tools and equipments and finishing tools; (8) method of fixing the mould for casting; (9) repairing of defects in a metal cast; and (10) method of preparing hollow images.

II. *ŚILPARATNA*[2]

This work belongs to the 16th century. The author is Srīkumāra, a Kerala Brahmin, who wrote it at the instance of King Devanārayāna, ruler of Ambalappuzhā, (central Kerala). It touches upon the subject of *cire perdue* casting in Part II, Chapter II under *Linga lakshanam*. In Chapter I, the different metals in which images can be cast are mentioned along with the merits and demerits of each (verses 38-41). In verse 44 are mentioned the places from where clay suitable for moulding is to be procured. In twenty-one verses (32-52) of Chapter II, the step-by-step procedure for making a hollow casting in metal is explained. Verse 53 mentions the method for casting a solid image. In certain respects the information is more complete than in *Mānasollāsa*.

Apart from the principal stages of *cire perdue* process like modelling, moulding, casting and finishing, the *Śilparatna* supplies some additional information. For example in Chapter I we have some general statements with regard to metals used for casting. Similarly in Chapter I, the places from where clay for moulding is to be procured are also mentioned.

The principal stages are:

A. *Modelling*: concerned with the preparation of a wax model for hollow casting.

B. *Moulding*: This can be subdivided into; (a) the different types of moulding media and their preparation; and (b) method of moulding.

C. *Casting*: This can be subdivided into: (a) dewaxing and baking the mould; (b) casting process; and (c) devesting the mould.

D. *Finishing*: concerned with the perfecting of a metal cast.

With reference to the metals used for casting "gold, silver, copper, brass, bronze, iron, lead and tin are the eight metals in which an image can be cast." Then follow the merits and demerits in the use of different kinds of metals. The four principal kinds are also enumerated (Chapter I verses 38-41).

With regard to the places from where moulding clay is to be procured. "Clay from holy sites, mountains, gardens of a sacred country are suitable for moulding" (Chapter I, verse 44).*†

Chapter II has a general introduction to the process of *cire perdue* casting: "Prepare an image with or without all the parts out of wax. It should be firmly encased in clay. After it is dried, the wax should be melted out. This should be filled with melted metal and thus a fine metal image has to be made. This process is being explained for the benefit of the craftsmen" (verses 32, 33).
Then follow the details of the technique.

A. *Modelling*

The *Śilparatna* describes hollow casting in detail and hence there is additional information with regard to the core compound and to the method of modelling in wax over the clay core. "Out of the second category of clay (i.e. semi hard clay—see below under moulding) prepare the core a little smaller in size (than the image required in metal) and smear it again and again each time when it is dry and finally smear it with strained diluted cowdung (juice). Apply wax sheet of required thickness all over this core and work out (the wax model with) all the features and according to the required size (of the image in metal). Work out the ornaments with wax threads using the tools made of the pith of tamarind tree or bamboo and polish and finish the model along with the ornaments" (verses 40-44).

B. *Moulding*

This text has some information with regard to the preparation of different types of clay compound for moulding as well as for making the crucible.

(a) The different types of moulding media and the method of their preparation: hard clay, semi hard clay, soft clay, very soft clay (these are for moulding purpose) and clay for making crucibles.

For *hard clay (Kathinā)* "Procure clay as described before (Chapter I, verse 44) or from an ant hill. Add brick powder and knead it very well. Mix with it arecanut-husk juice in pure water in required proportion. Pound this composition with pestle on a mortar. Thus the required hard clay (*Kathinā)* is produced." (verses 35, 36).

For *semi hard clay (Manda-Kathinā)* "Add cowdung to the above and it becomes semi hard" (verse 37).

For *soft clay (Mṛidu)* "Take four parts of pot clay (powdered baked pots) and one part of ordinary clay and grind them well together on a mortar with a pestle" (verses 37, 38).

For *very soft clay (Mṛidutarā)* "Mix the above with cowdung and it becomes softer" (verse 38).

Clay for making crucibles (*Mushā karanā mṛid)* "Mix charred rice husk powder, pot clay (powder of baked pots) and finely severed cotton cloth together and pound them well on mortar with a pestle. Thus is prepared firm and compact clay suitable for a crucible" (verses 39, 40).

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*Chapter II, verse 35 adds clay from ant hills also to the list.

†तीर्थक्ष त्राचला रामपुण्यदेशोद्भवां मृदम् ।।४४।।

(b) With reference to the method of moulding: "Then apply wet, very soft clay evenly over it (wax model). After it is dry, apply soft clay over it and dry it again. When it is dry apply hard clay and bind (the whole) firmly with black iron strap. Over this apply again hard clay until the mould is strong and satisfactory. The iron strap should pass through the unimportant parts of the image" (verses 44-47).

C. *Casting*

(a) With reference to the processes of dewaxing and baking the mould: "After the mould is dry, place it over a pile of firewood and bake it with the aid of machines (probably meaning bellows), drain out the wax and continue heating it" (verses 47, 48).

(b) With reference to the casting technique: "As you notice through the hole meant for casting, the inside glowing with the colour of a pumpkin flower, remove it (mould) from the fire and place it with the mouth upward in a pit (already prepared). Lift quickly and carefully the ready molten metal in the crucible and pour (the molten metal) through the mouth of the hole (pouring cup) until the mould is completely filled. Cover the mould with sand and allow it to cool by itself" (verses 48-51).

(c) With reference to the process of devesting the mould: "The skilful craftsman should break open the mould carefully with sharp and pointed instruments" (verse 51).

D. *Finishing*

"With the aid of various tools the different parts of the image should be chased, finished and made very beautiful. Thus, an intelligent person should get metal images prepared by an expert craftsman (verse 52).

The process of solid casting has been described in one verse as under: "For a solid metal image prepare a model in solid wax, mould and cast it as described before" (verse 53).

This work does not provide the following technical information on the subject. They are: (1) the composition of the wax used in modelling; (2) the method of fixing the sprue; (3) the use of core pins to hold the core and the mould in position after the wax is drained out; (4) method of making the crucible and melting the metal; (5) method of making the kiln for baking the mould for casting; (6) method of making the furnace for melting the metal; (7) method of ascertaining the ratio of different metals used for casting in comparison to the weight of the wax model; (8) the temperature required to melt different metals; (9) modelling tools, foundry tools and equipments and finishing tools; (10) repairing of defects in metal casts.

III. *MĀNASĀRA*[3]

According to ancient traditions, the author of this text seems to be a mystic sage of the old. Chapter LXVIII of this text deals with the method of lost wax process termed *Maduchchhista vidhānam*. Only a few selected verses in this work touch the actual technical process of casting, the rest deal with religious aspects. Verses 12, 21, 22, 23, and 26 deal with certain aspects pertaining to different stages in the method of casting an image in metal. This can be divided into three different technical stages to be followed in casting a metal image. Apart from the three principal stages of *cire perdue* process like modelling, moulding and casting the *Mānasāra* supplies one additional information regarding the repair of a defective cast. The principal stages are:

A. *Modelling*: concerned with the preparation of a wax model for hollow casting.

B. *Moulding*: concerned with the preparation of a clay negative (mould) of the wax model for casting.

C. *Casting*: This can be subdivided into three successive processes as under: (a) dewaxing and baking the mould; (b) casting process; and (c) devesting.

A. *Modelling*

"According to the śāstras (rules), the *Vardhakī* (*Sthapati's* assistant) should prepare the (image of) wax under instructions of the *Sthapati* and after meditating upon the form of the deity which he has to make" (verse 12).

The modelling process is described below:

"After determining the various measurements (length, breadth and height) of the image, the *Śilpī* (craftsman) should apply wax to the thickness of two or three *angulas* over it (core)" (verse 21).

(verses 13 to 18 in which *Kshanikabera* (temporary image is referred to mention some kind of inside material apparently the core over which the wax model is worked out).

B. *Moulding*

"Over this (wax image) apply clay and dry it (verse 22).

C. *Casting*

(a) With reference to the dewaxing and baking processes: "Drain out the wax by baking the clay mould" (verse 22).

(b) With reference to casting technique: "According to the preference of the donor (with regard to the metal in which the image is to be cast) fill the mould with molten metal" (verse 23).

(c) With reference to devesting process: "Sprinkle water over the mould and break it" (verse 23).

The technique of repairing a cast is described as under: "If there be any minor defect in the cast, it should be repaired. But if the head or the middle of the body is damaged it should be discarded and a fresh image must be modelled and cast" (verse 26).

This work does not provide many factual information regarding several technical aspects of *cire perdue* casting. They are: (1) the composition of the wax used in modelling; (2) method of fixing the sprue; (3) places from where moulding clay is procured; (4) different types of clay preparations used in *cire perdue* casting; (5) method of preparing the core; (6) the use of core pins to hold the core in position after the wax is drained out; (7) method of ascertaining the ratio of different metals used for casting in comparison to the weight of the wax model; (8) method of making the crucible; (9) method of making the kiln and baking the mould for casting; (10) method of making the furnace and melting the metal; (11) the temperature required to melt different metals; (12) fuel used for heating the mould and the crucible: (13) method of fixing the mould for casting; (14) modelling tools, foundry tools and equipments and finishing tools; (15) method of finishing the metal cast; (16) method of preparing solid images.

Even the information provided is very limited. Hence, this text has to be considered as the least informative among the three ancient works that deal on the technical aspects of *cire perdue* casting.

REFERENCES

[1] Somesvara Bhūlokamalla, *Mānasollāsa*, Vol. I, Chapter XI, verses 78 to 97; *Abhilasitartha chintāmani*, Part I, verses 76 to 96.

[2] Srīkumāra, *Śilparatna*, Part II, Chapter I, verses 38 to 41 and Chapter II, verses 32 to 52.

[3] Prasanna Kumar Acharya (ed.), *Mānasāra*, Vol. III, Chapter LXVIII verses 12, 21, 22, 23, 26.

TABLE

Observations showing the omissions in the technical information provided on *cire perdue* casting in the three ancient texts.

	Mānasollāsa	*Śilparatna*	*Mānasāra*
	Does not provide information on:	Does not provide information on:	Does not provide information on:
1	The composition of the wax used in modelling.	The composition of the wax used in modelling.	The composition of the wax used in modelling.
2	Mode of procuring and preparing different types of clay compound used in *cire perdue* casting.		Mode of procuring and preparing different types of clay compound used in *cire perdue* casting.
3		Method of making the crucible and melting the metal.	Method of making the crucible and melting the metal.
4	Fuel used for heating the mould and the crucible.		Fuel used for heating the mould and the crucible.

5	Method of making the kiln and baking the mould for casting.	Method of making the kiln and baking the mould for casting.	Method of making the kiln and baking the mould for casting.
6	Method of making the furnace for melting the metal.	Method of making the furnace for melting the metal.	Method of making the furnace for melting the metal.
7	Modelling tools, foundry tools and equipments and finishing tools.	Modelling tools, foundry tools and equipments and finishing tools.	Modelling tools, foundry tools and equipments and finishing tools.
8	Method of fixing the mould for casting.		Method of fixing the mould for casting.
9		Temperature required to melt different metals.	Temperature required to melt different metals.
10		Method of ascertaining the ratio of different metals used for casting in comparison to the weight of the wax model.	Method of ascertaining the ratio of different metals used for casting in comparison to the weight of the wax model.
11		Method of fixing the sprue.	Method of fixing the sprue.
12	Repairing of defects in a metal casting.	Repairing of defects in a metal casting.	
13			Method of finishing a metal casting.
14			Method of preparing solid images.
15			The method of preparing the core for hollow casting.
16			The use of core pins to hold the core in position after the wax is drained out.
17	Method of preparing hollow images.		

EXISTING TRADITIONAL TECHNIQUES IN INDIA

India's long tradition in the art of *cire perdue* casting survives among a few families of hereditary craftsmen. This is mainly because metal icons hold a prominent position in the religious worship of the Hindus. All along these artists had the patronage of the wealthy temples, religious institutions and deeply devoted Hindus who use icons for worship at their homes. This may be the reason that these craftsmen are found settled around famous religious centres. For centuries, the particular community known all over India as Viśvakarmās have been responsible for preserving our heritage in this art. At the present day, the expert practitioners in this vocation are mostly found in South India. In Tamil Nadu, they are found settled in the districts of Tanjavoor, Tiruchirapalli, Madurai, Ramanathapuram, Chingalpet, Tirunnelveli, Coimbatore, Salem, South Arcot and Kanyakumari. In Andhra Pradesh, a few families still practise this art in the vicinity of the famous temple of Thirupathi. They claim that their ancestors settled there during the Vijayanagar period. In the Karnataka State, at Bangalore and Mysore there are a few families following this vocation. In Kerala, there are number of places where the tradition in *cire perdue* casting exists. In the North, this art almost died out due to religious persecution by the Muslim rulers. However, in the holy cities of Varanasi, Mathura, Hamirpur and Srinagar (Mahoba district in Uttar Pradesh)[1] there are few families keeping alive this art. At Sawai Madhopur in Rajasthan this technique is adopted for casting jewellery. A crude form of *cire perdue* casting persists among some tribal craftsmen in Bengal, Bihar, Orissa and Madhya Pradesh. The families engaged in this art in modern Nepal seem to be the descendants of the craftsmen of the Pala period of Bengal. The technique still followed by the ***Sthapathis*** of Swamimalai in Tamil Nadu and Newari artists of Patan in Nepal holds the best of the tradition in this art. In this study, the materials and methods of the Swamimalai craftsmen are described in detail and compared with those in vogue in other parts of India.

THE STHAPATHIS OF SWAMIMALAI

The term *Sthapathi* is used by craftsmen who engage themselves in the making of religious icons and images. They belong to the *Kammālar* (Tamil, Malayalam; *Kamsālā* — Telugu; *Pānchālā* — Canarese) community which practises various other crafts like carpentry, goldsmithing, blacksmithing, coppersmithing and stone carving. The *Sthapathis'* claim a higher social status in their community. They have adopted certain ways of living like the Brahmins. The *Sthapathis* of Swamimalai trace their ancestry to Akora Bhadra Acharya who came to settle there after the construction of the famous Subramanya *(Kārtikeya)* temple. Today, there are seventeen families and among them twenty-six members practise this art.

The *Sthapathis* are supposed to be well versed in the iconographic injunctions pertaining to the making of various icons. Besides, for success in their undertaking, they are supposed to do certain religious services before commencing a new work. But, actually many of the craftsmen, engaged in this art, are ignorant about the iconographical rules and do not strictly perform the religious services before beginning their work. By practice, the *Sthapathis* know the various proportions of the different parts of the image they make. They also know the *dhyānas*, the ornaments, the weapons, the postures of the arms and legs, as well as the expressions of the gods, whose images are to be made. With the aid of these and his imagination, he proceeds to make the wax model of the image.

Almost all the images made by the *Sthapathis* are solid castings. They say that their religious ordinance prohibits casting of hollow icons. Probably, it may be due to the prohibition in using hollow images for religious services. However, they know the technique of hollow casting also. The process may be divided into four principal stages.

A. *Modelling*: This can be subdivided into: (a) modelling media; (b) modelling tools; (c) preparation of a wax model. Before moulding the wax model is weighed to determine the ratio between the weight of metal needed for casting and the wax model.

B. *Moulding*: This can be subdivided into: (a) moulding media; (b) method of moulding.

C. *Casting*: This can be subdivided into: (a) foundry establishments for dewaxing, baking, casting and devesting; (b) dewaxing and baking the mould (burn out process); (c) alloy for casting; (d) melting process and casting; and (e) devesting the mould.

D. *Finishing*: This can be subdivided into: (a) removing the extra attachments (pruning); (b) pickling; (c) chiselling; (d) tapping the blow holes; (e) shaping and chasing; (f) filing; (g) scraping; (h) engraving; (i) sanding; (j) cleaning; and (k) polishing.

A. *Modelling*

(a) The modelling medium used is beeswax *(thenmezhuku*—Tamil; *Moma*—Hindi) with additives such as dammer rosin *(kuṅguliyam*—Tamil; *rāla*— Hindi) and groundnut oil *(kadalai ɛṇṇai*—Tamil; *mūṅgaphali kā tèla*—Hindi). The craftsmen prepare two different compounds, one for modelling the wax model and the other for modelling the ornaments. The ratio of their ingredients are as follows:

Compound for modelling the wax model *(kalarpumezhuku*—Tamil; *Mayin*—Hindi): twenty parts beeswax, twenty parts dammer rosin and five parts groundnut oil.

Compound for ornaments: seven parts beeswax and three parts of the compound prepared for the wax model.

The compound for the wax model is prepared as follows: Dammer rosin is ground to powder, weighed and is mixed with groundnut oil. To find out the correct composition of the mixture a little of the mixture is rolled into a ball and is thrown on the ground. If it splits and falls apart into small particles, the mixture is in correct proportion. This mixture is heated over a low fire on a shallow pan and beeswax is slowly added in small bits. When the required amount of wax is added the mixture is stirred and blended. As soon as the amalgam is ready, it is removed from the fire and filtered through a piece of muslin cloth into a pan containing cold water. The filtered mixture which solidifies on the surface of the water will be free from impurities.

Almost the same technique is used by the craftsmen in other parts of India. However, the composition of their wax medium differs.

The artisans of Thirupathi[2] and Bangalore[3] use a compound consisting of four parts of beeswax and one part of charcoal powder or lamp black. The craftsmen in Pondicherry use a compound consisting of eight parts of beeswax, four parts of rosin, and one part of castor oil.[4] The craftsmen in Pazhayanoor in Kerala use a composition consisting of hundred parts of beeswax, twenty parts of rosin and one part of charcoal. At Kalahasti in Andhra Pradesh, craftsmen engaged in casting bronze vessels use a composition consisting of five parts of beeswax, seventeen parts of rosin and six parts of margosa oil.[5] The Kasar craftsmen at Jagdalpur (Bastar district in Madhya Pradesh) use a compound consisting of four parts of beeswax and one part of sesame oil.[6] The Kainkuya Mals at Bankura in West Bengal use a composition consisting of dhuna, a resinous substance obtained from the sal tree — *Shorea robusta* and mustard oil.[7] The Thetari Ranas of Mayurbhanj in Orissa use beeswax and mustard oil or groundnut oil.[8] The Lowadia metal smiths of Bihar use a composition consisting of dhuna and mustard or groundnut or kochra oil (kochra oil is extracted from the fruits of the *Mahua* tree *Bassia latifolia*).[9] The Visvakarmas of Varanasi use a compound consisting of two parts of beeswax, four parts of rosin and one part of mustard oil. The craftsmen at Sawai Madhopur in Rajasthan use seven parts of beeswax, forty parts of rosin and eleven parts of sesame oil.[10] These data show the availability of raw material and probably the climatic conditions of a particular place play a prominent role in the preparation of the compound.

(b) The different tools and equipments used while modelling a wax model by the *Sthapathis* of Swamimalai are as follows:

A wooden roller (*mezhukuthadī*—Tamil), wooden ruler (with *yavā* measurements), a board having vertical and horizontal liner divisions (*lambapalakāy* — Tamil), try square, compass, calliper, sandal wood spatulas of different shapes and sizes (*mezhuku kuchi* — Tamil), steel spatulas (*mezhuku kaṭṭi* — Tamil), a small iron brazier lighted with charcoal, pincers, soldering iron (*pathikkōl* — Tamil), a smooth wooden slab and *oḍi ōlai* — Tamil which is a fresh cocoanut palm leaf folded to indicate the various measurements of the image to be made. This is done in an ingenious way by bending and folding a green palm leaf before commencing the work.

The tools used for modelling by artisans of Varanasi are as follows:

A wooden roller (*belana*—Hindi), a compass (*compass*—Hindi), a calliper (*gōla compass* — Hindi), wooden modelling tools* (*kalama*—Hindi), copper or brass modelling tools (*kalama* — Hindi), a plainer (*thapi* — Hindi), scissors (*kaiñchī* — Hindi), a try square (*gōniyā* — Hindi), steel knife (*pattī* — Hindi), a small charcoal brazier (*bhaṭṭhī*—Hindi), a marble slab and pincers.

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* The wooden modelling tools are made from the pith (*viram* – Tamil; *Hīra* – Hindi) of ebony wood (*ābanūsa lakadī* – Hindi) or tamarind – *pulī* – Tamil; *Imalī* – Hindi).

(c) The technique of preparing a wax model (*karuvū* — Tamil):

The *Sthapathi* sits comfortably over a plank on the ground. The wax compound is kept in a vessel containing lukewarm water to keep it pliable for working. By using the roller and a slab a number of wax sheets of required thickness are prepared for modelling. Similarly wax rods of different length and girths are also prepared and kept ready for modelling. A lighted iron brazier is kept in front to warm the wax while modelling. The *Sthapathi* first prepares a rough skeleton in wax of the different parts of the image. All main parts of the figure such as the head, torso, hands and legs are modelled separately and he uses the spatulas to shape them as required. Whenever necessary, he warms the parts to facilitate modelling. The compass and callipers are used for measuring the proportions of length and girth of the wax model. After all the units are modelled the *Sthapathi* attaches each of them to the appropriate places of the body. For this he thaws the ends to be attached by holding in both hands each part over the lighted brazier for a few seconds. Sometimes a soldering rod is used for the purpose. When the wax at the ends turns a little soft, they are pressed together and fused. The joints are further mended by dripping melted wax from the end of a steel spatula over the fused area and wooden spatula is used to perfect the modelling. Thus, after uniting all the parts and shaping the whole figure, he begins the modelling of the ornaments using the specially prepared wax compound. This wax is more ductile than the wax used for modelling the figure. Rolling out wax threads of required sizes he presses them on to the body of the figure and designs the ornaments. Picking up a live charcoal with a pincer from the brazier he warms the attached ornaments and fuses them to the body of the figure. After this the *Sthapathi* fixes the wax model on the pedestal and adjusts the balance. The fixing of the wax model on the pedestal is done only in the case of small models. For bigger models the pedestal is prepared separately. The *lambapalakāy* which is meant for finding out the plumb line measurements of an image is seldom used. This is because by experience the *Sthapathi* has a keen eye to spot out the defects in the balance and correct it without this aid. An obvious fact is that the details of the features and ornaments are not done on the wax model. They are left to be worked out by chiselling and engraving on the metal cast.

At the Bangalore Bronze Production Centre of the All India Handicrafts Board, a slightly different method is followed in modelling the wax model. First, a wax panel is prepared over a smooth board and a sketch of the figure is made over the panel. This is very helpful for the correct delineation of the vertical and horizontal measurements of the figure to be modelled. A high relief modelling is then done over the drawing. After modelling the front view, the figure is cut out from the panel with a heated steel spatula and is carefully lifted from the board. It is reversed and kept over a soft padding for the modelling of the back side. At times the limbs are detached and separately worked out and attached.[11]

Next, he fixes runners made of wax rods to the ends of the palm, legs and other areas that are away from the main body. These rods will turn into supply channels to these parts after the wax is drained out during dewaxing. At the base of the pedestal he fixes a thick rod of wax to serve a sprue. This projects away from the image to the intended thickness of the mould. The free end of this rod is shaped like a cone, which will later form the pouring cup. In the case of bigger images two wax rods are attached; the second one serves as an air vent. No other air vents are used. In some complicated images, more than one pouring cup is formed in order to facilitate simultaneous filling of melted metal into the cavity of the mould. The sprue, vents and runners are attached suitable for the gravity-cast system. (See charts at the end).

The wax model is now weighed and the metal required for casting is calculated. The ratio for different metals in relation to the weight of wax is as follows: Bronze and brass ten times, silver fifteen times and gold twenty times. While melting, a little more than the actual amount calculated is melted in order to meet any eventuality.

B. *Moulding*

(a) Combination of the following basic materials are used as moulding medium. They are: loam or river bed clay or fine clay obtained from fields, cowdung and sand. The loam is procured from the river Kaveri which runs very near to Swamimalai.

It will be interesting to note that locally available material plays a major part in determining the composition of the moulding materials. The craftsmen at the Bangalore Bronze Production Centre use the following basic materials:[12] burnt clay (removed from used moulds ground to fine powder and sieved), cowdung, jute cuttings, rice husk, sand and ordinary red plastic clay.

The artisans of Pondicherry[13] use plastic clay, saline clay, ordinary clay and cowdung as basic materials.

In Kerala the craftsmen at Kunnankulam use finely ground brick powder, fine plastic clay, jute cuttings and cowdung as basic materials.

In different parts of Andhra Pradesh they use different basic materials according to their availability. At Thirupathi the craftsmen use[14] light yellow clay *(paṭṭa miṭṭi* or *jeḍu miṭṭi* — Telugu), jute fibre and castor oil. The bronze utensil makers of East Godavari district at the towns of Rajamundry, Kakinada and Chitrade collect the alluvial soil of river Godavari when it is in spate. Since fresh clay is not suitable for moulding, they mix used clay along with the fresh one in three to one proportion and cowdung. At Kalahasti near Thirupathi clay from the river Swarnamukhi is used along with jute cuttings.[15]

The metal founders of Varanasi in Uttar Pradesh use[16] yellow clay *(pīli miṭṭi* — Hindi), red clay (*lāl miṭṭi* — Hindi), severed cotton, rice husk and cowdung (specially calf dung) as basic materials. Both types of clay are got from the banks of the river Assi near the village of Sunderpur, Varanasi. In some areas in Uttar Pradesh the craftsmen use, *bajra* husk, horse dung and chaff (*bhūsā* — Hindi) as additives to clay.[17]

The Kainkuya Mals of Bengal[18] on the other hand use loam taken from around the roots of bamboo and uncrushed sand as basic materials.

The artisans of Jagdalpur in Madhya Pradesh use reddish brown river clay *rūi miṭṭi* — Hindi), *Kolli miṭṭi* or *bhuso miṭṭi* — Hindi) gathered from the banks of tanks, ant hill clay and goat dung as basic materials.[19]

In Orissa the metal workers known as Thetari Ranas[20] use clay from paddy fields (*bila miṭṭi* — Oriya), cowdung, fine sand, ant hill clay, gunny bag cuttings, green leaves and grass boiled in water as basic materials.

The artisans all over use iron bands or metal wire for reinforcement.

(b) The method of moulding (*mankaṭṭal* — Tamil) used at Swamimalai is as follows:

Moulding is done in three coats. For the *first coat* a slurry is made by mixing two parts of loam with one part strained cowdung. This slurry is applied all over the wax model leaving the tips of the sprue and the vent. It is left to dry in the shade. This coating is done in three layers, until a fine surface is formed over the entire wax model. Any crack that appears is carefully filled up. Great care is taken to mould all the parts and to remove all the air bubbles and grits. For the *second coat* one part of clay and two parts of sand are well kneaded into dough and then applied. This coat is done in two layers. After the first layer, iron bands are wound round the entire mould, over which another layer of clay compound is applied and each layer is allowed to dry before the next one is applied.

For the *third coat* a padding of the same compound is again applied in order to strengthen the mould. In the case of big figures, further reinforcement is done at the time of applying the third coat. The tips of the sprue and vent are shaped like a cup. The mould is left to dry completely.

At Pondicherry the following process of moulding is adopted. A mixture of plastic saline clay and cowdung is ground to a fine paste on a grinding stone, dried and stored in a pot for later use. When required, it is soaked in water for about half an hour, kneaded well into a dough and ground to a fine paste. This paste is used for the *first coat*. Preparation of the compound used for the *second coat* is as follows: The sand brought from the river Sankaraparani is sieved through a fine mesh and is added to ordinary field clay. The mixing is done with spade and left for about twelve hours. Next, it is trampled with legs, prepared and stored. Whenever required, it is soaked in water for about fifteen minutes, kneaded into dough and used for the *second coat* for strengthening the mould.[21]

The following technique is adopted for moulding at Varanasi: For the *first coat*, one part of soaked red clay thoroughly mixed with approximately point zero two part (by weight) of severed cotton by beating with a wooden mallet. Next three parts of yellow clay is powdered and added to the already prepared mixture. It is kneaded well into a dough and kept off for a day. Before use a little water is added and again kneaded to make ready for moulding. Enough mixture is prepared in one lot for the entire work. A thin layer is first applied all over the wax model taking care to cover all the minute details, leaving the tip of the sprue and the vent. It is left to dry for two days. Then another layer is applied over it and is left to dry in the sun.

For the *second coat* four parts of red clay is soaked overnight and one part of rice husk is added to it in the morning and kneaded well together. The mixture is left for a day before use. Two layers of this clay are applied. After the first layer, iron bands or wires are wound round the mould for reinforcement. Then the second layer is applied and the mould is strengthened. Each layer is allowed to dry before the next one is applied. The tips of the sprue and vent are shaped like cups and the mould is left to dry completely.

A different compound is prepared for repairing the cracks that appear over the mould after the first coating. For this cowdung (calf dung is preferred as it is said to have more plasticity) is mixed in water, strained and allowed to stand for three or four days. When it gets thick then yellow clay powder is mixed with it and made into a dough. This compound is also used for filling the cracks and for making a core in hollow casting.

A very interesting technique is adopted by the Kainkuya Mals of West Bengal for applying the investment. Like the other craftsmen mentioned earlier they do not fix a wax rod for the sprue instead a different technique is followed. For the *first coat*, a thin slurry of sand free fine plastic clay is applied over the entire wax model and is left to dry completely in the shade. When the mould is bone dry, a hole is bored through the clay until it touches the wax model inside. In this hole, a bamboo-split is inserted and packed with clay and shaped like a peak. The mould is then allowed to dry. When it is completely dry, the bamboo-split is pulled out thus creating a channel leading to the wax model. After creating this passage, the *second coat* of coarse clay is applied all over the entire mould. The tip of the passage is shaped like a cup.[22]

It is interesting to record the techniques followed by the craftsmen near Thirupathi. Here, the clay for moulding is obtained from the sugarcane farms in the villages. It is cleaned, the grits are removed, kneaded into fine powder and pieces of jute cuttings are added to it. This mixture is kept soaked overnight and beaten into a paste. Before moulding, a little castor oil is smeared over the wax model and the *first coat* is applied to one-fourth inch thickness. The mould is dried in the sun for four to five hours. After this it is tied firmly with an iron wire and placed in an inclined position on a pan over a lighted brazier, allowing only the upper portion of the mould to get heated. The wax inside melts and drains out through the sprue and vent holes into a pan containing water. After the wax is melted out, the mould is taken off from the pan and a half an inch thick *second coat* is applied over the first one. The mould is left to dry in the sun.

Yet, another moulding process is used for making copies of simple wax models by these craftsmen. The wax model is first coated with a thin layer of castor oil for easy release of the mould. The entire model is then covered with the moulding clay and left to dry. When the mould is half dry, it is cut open laterally into two halves. The wax model is taken out and the two halves of the mould are then reset together, encased with another coat of clay and bound with a thin wire. The mould is further strengthened with a thick application of clay and left to dry completely.[23]

C. *Casting*

(a) The foundry establishment at Swamimalai consists of the following items:

A fan-draughted open ground forge (for dewaxing), a roughly fabricated oven (for baking), a down draught furnace lined with fire brick on the sides and at the bottom for melting the metal a small pit and a heap of sand and earth to bank the mould while casting, a shallow pan or bowl, a hand blower, an electric blower (connected to the melting furnace), lifting tongs (*chūḷa koradu*—Tamil), clip tongs (*idukkī* — Tamil), shanks, skimmer (*oulaī kambi* — Tamil), long ladles, graphite crucibles (*kūvai* — Tamil), pointed chisels (for devesting), hammer (*chuthy* — Tamil) cowdung cakes (*varalī* — Tamil) and charcoal.*

b) The technique of dewaxing and baking the mould (burn-out process):

For *dewaxing*, first enough fuel is fed in the pit of the forge and the fire is lit and fanned with the help of the hand blower. Next, the inside of the pouring cup of the mould is brushed to remove any dirt sticking to the tip of the sprue and vent. After that the surface around the pouring cup is heated over the flame. This is done to prevent the mould from cracking due to the expansion of the wax inside, while heating the entire mould. Next, two or three bricks are placed at both the lateral sides of the forge. The mould is then kept horizontally in a slightly slanting position over the bricks, with the pouring cup projecting a little beyond the bricks. A pan containing cold water is placed, just below the pouring cup and the entire mould is heated carefully. When the mould gets warm, the wax inside begins to melt and oozes out through the sprue and vent openings and drips down over the surface of the water in the pan and solidifies. Thus almost all the wax inside the mould is recovered.

The craftsmen of Pondicherry, Varanasi, Thirupathi and Kunnankulam too salvage the wax for repeated use.

For *baking*, a layer of cowdung cakes is spread on the floor of the oven, over which a layer of charcoal is spread and the dewaxed mould is arranged on it. It is covered over with cowdung cakes and the fire is lighted. Fuel is replenished at intervals to keep the firing constant. With the slow rise of the temperature, whatever wax is left inside the mould burns off. Heating is continued until all the moisture in the mould is expelled.** The inside cavity of the mould is watched through the sprue hole and when it glows with a bright red colour the mould is deemed ready for casting.

The well-baked hot burning mould is very carefully lifted with tongs and is deposited inside the pit with the pouring cup facing upward. Its sides are banked with dry earth or sand to keep it steady while casting.

The craftsmen at Kunnankulam use an oven-cum-melting furnace for baking the mould and melting the metal simultaneously. The oven has a perforated floor and the moulds are arranged inside it. The furnace for melting the metal is situated below the perforated floor. While melting, the flame from the furnace enters the oven chamber through the holes on its floor to bake the mould. The chamber has two terracotta lids for closing it while baking and a number of holes on its roof to serve as chimneys. Almost a similar oven-cum-melting furnace is used by the craftsmen at Thirupathi.[24]

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*Dried cocoanut husks are used by craftsmen in Kerala and hard coke by the craftsmen at Varanasi.

**This is very important because water vapour entrapped inside the mould will turn into steam while the molten metal enters it. This will result in violent bubbling froth and showering of hot metal around causing serious accidents, besides ruining the cast.

The artisans of Pondicherry bake the mould with cowdung cakes and charcoal. The mould is set over a layer of charcoal cinders and covered completely with cowdung cakes. The fire is fanned with a fan made of palmyrah-leaf or a winnowing tray. Once in every fifteen or twenty minutes the cowdung cakes are replenished to keep on the fire to bake the mould properly. When the mould is ready it is arranged for casting as described earlier.[25]

The Varanasi craftsmen use a grid-iron fitted pit-oven for baking the mould. The dewaxed mould is arranged on the grid-iron and is covered with cowdung cakes and broken pottery. Firing is done with wood from the hearth below and when ready, the mould is arranged for casting as described before.

(c) The *Sthapathis* of Swamimalai use the following metal composition for their casting: Twenty parts of copper, four parts of brass and one part of lead.

(d) The process of melting and casting: Simultaneous with the baking of the mould for casting, the melting of metal is undertaken since the pouring has to be done while the mould is hot.

A layer of charcoal is spread inside the furnace and at the centre a suitable crucible is placed with fuel filling all around it up to the brim. The fire is ignited and fanned with an electric blower. Scrap metal which is used to make the alloy is preheated and broken to pieces. Copper which is the first metal to be melted is loaded inside the crucible and the mouth of the furnace is covered with a lid to prevent loss of heat. Melting is watched through the peep hole provided on the lid and every fifteen or twenty minutes the *Sthapathi* lifts the lid to maintain the needed quantity of fuel inside the furnace. He also makes sure that the crucible is in proper position. If it is tilting he puts it in proper position with clip tongs, replenishes the fuel to keep the fire constant and puts back the lid again. When the *Sthapathi* notices that the copper has melted* he cleans it by throwing some borax (flux) on the top of the melted liquid and stirs it. After that he adds brass and when the brass melts finally he adds lead. By now the alloy is fully melted and is deemed ready for casting. The liquefied metal is tested with the skimmer by inserting it inside and taking it out. If the metal does not stick to the rod it is in a proper state for pouring into the mould. The blower is put off and the crucible is lifted out from the furnace with the help of lifting tongs and placed over a layer of bricks on the foundry floor. The metal is skimmed and the slages are removed with the skimmer. A circular ring of rags (*mukhattuṇi* — Tamil), is placed around the pouring cup to prevent the metal from spilling and to support the crucible. The crucible is lifted with the help of clip tongs and brought near the mouth of the mould, tilted carefully and the melted metal is poured in a continuous stream into the cavity of the mould**

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*It is determined by the colour of the fume that emits from the metal inside the crucible.

**A pouring shank is used for lifting heavy crucibles for big castings and requires the help of two or more assistants.

The metal quickly fills the cavity and touches the brim of the vent and pouring cup. Pouring is stopped for a while and the mould is watched. If the metal sinks down fresh metal is supplied until there is no more sinking. If any liquid metal is left off in the crucible it is poured into a small clay container. The crucible is kept back inside the furnace to prevent cracking due to sudden cooling. The hot mould is covered with sand or dry earth and is left for gradual cooling. Usually, it takes ten to twelve hours for the mould to cool completely. The tools are put back in their proper places. The *Sthapathi* now waits to see the results of the operation.

It is interesting to note that the *Sthapathi* is very particular not to do the casting during *Rāhu kālam* a particular time of each day, which is considered inauspicious to initiate any new undertaking.

Almost similar casting procedures are followed by the craftsmen in other places, though occasionally different compositions of metal are used.

The artisans of Pondicherry use four parts of copper and one part of brass to make their alloy. They feel that this proportion will be soft and that the details can be worked out easily to a greater degree of perfection.[26]

The craftsmen near Thirupathi use thirty six parts of copper, twenty seven parts of brass, one part of lead and one part of zinc to prepare their alloy.[27]

The craftsmen in Sawai Madhopur in Rajasthan use an alloy (*kānsi* — Rajasthani; and local technical language *dharkrī*) which is a form of bell metal composed of sixteen parts of brass and six parts of zinc.[28]

In Punjab and Kashmir alloy known as *phūl* or *kānsi* is used. It consists of four parts of copper and one part of tin.[29]

(e) The method of *devesting* the mould: When the mould is quite cool it is taken out from sand or earth. The hard baked clay is knocked off carefully with chisel and hammer. If it is a hollow casting the inside core is also removed.

D. *Finishing*

The image that comes out of the mould needs various treatments before it is made suitable for display or installation. For this the *Sthapathi* adopts the following step by step procedure:

(a) The metal rods of the sprue, vent and runners are first cut off with a hacksaw just a little above their attachment to the body of the image. The stumps that remain are chiselled carefully and later filed and merged with the contour of the image, except in case of bigger images that require fixing to pedestal separately cast. Similarly, other protrusions and flashes are removed with cold chisels and files.

In the case of hollow castings, the core pins are also removed while *pruning*. The points of their attachment are then filed and merged with the contour of the image.

(b) The removal of fireskin caused by oxidation is known as *pickling*. The cast is kept immersed in a dilute acid solution consisting of five parts of water and one part of nitric acid for some time. Then it is removed, rinsed with cold water and cleaned.

(c) *Chiselling* is the technique used for working over the cast to perfect the contour.* For this the *Sthapathi* uses an array of cold chisels such as: flat chisel (*nalavāya veṭṭiriṁbu* — Tamil), convex chisel (*vaḷavu veṭṭirimbū* — Tamil; *valu pōgarā* — Telugu), concave chisel (*uḷḷukkuvaḷavu veṭṭiriṁbu* — Tamil; *tamara pogarā* — Telugu; *powari* — Hindi), diamond pointed chisel (*kīrtīmukam*—Tamil; *gorū pogarā*—Telugu; *āgé muhā chaurasiyā* — Hindi), lozenger-shaped chisel (*kīruttanam* — Tamil) and different types of hammers such as pin head hammer, flat hammer, square faced hammer and ball peen hammer.

(d) The blow holes and other dimples that may appear while chiselling need to be plugged. This is done by *tapping* in cold metal and perfecting the seam. This is known as cold finishing.

(e) The chiselled image now requires *chasing* to perfect the surface. For this the *Sthapathi* uses the following tools: square-headed tool (*chatura metiyan* — Tamil; *deṭṭe pogarā* — Telugu; *chaurasiyā* — Hindi), dome-headed tool (*uruṇda metiyan* — Tamil; *gola chaurasiyā* — Hindi), curved (light) shaping tool (*chaumitiyan pōrai* — Tamil), curved tool (*vaḷavu porai* — Tamil), bangle tool (*kapu porai* — Tamil), liner (*kaṁbītiyan* — Tamil; *rèkhā pogarā* — Telugu; *sūttanā* — Hindi), flower design tool (*pūporai* — Tamil; *kolupo pogarā*—Telugu), eye tool (*kaṇṇu porai* — Tamil), circular headed tool for rounding of corners (*maṭṭala veṭṭiriṃbu* — and planisher *mṛitunam* — Tamil).

(f) *Filing* is done to bring about further finish to the surface of the image. For this the *Sthapathi* uses the following types of files: (*chatura aram* — Tamil; *chaukora reti* — Hindi), round file (*uruṇda aram* — Tamil; *gola reti* — Hindi), half round file (*araivaṭṭa aram* — Tamil; *ardhagola reti* — Hindi), triangular file (*muppaṭṭai aram* — Tamil; *tiṅtirā reti* — Hindi), double headed file (*talai aram* — Tamil), knife edged file (*katti aram* — Tamil), needle file (*kuchchi aram* — Tamil) and flat file (*paṭṭai aram* — Tamil; *chipaṭṭi reti* — Hindi). With these different types of files he files the entire surface of the image and makes it ready for scraping.

(g) *Scraping* is done to smoothen the surface and sharpen the edges. For this the *Sthapathi* uses the following tools: flat scraping chisel (*chīuli* — Tamil; *chivvelegā* or *chīvve pōgarā* — Telugu), circular headed scraping chisel (*maṭṭuli* — Tamil) and curved chisel (*vaḷavu uli* — Tamil).

(h) *Engraving* is done with different types of engraving tools (*nagāsi pokkā* — Tamil) to work out the details of the different ornaments like bangles, necklace, crown, dress and delineation of the eyes, ears, mouth, nails, etc. In this job the *Sthapathi* assumes the role of an expert jeweller.

(i) *Sanding* is done to remove all file marks and fine scratches before polishing. With different grades of emery papers the surface is rubbed and finely smoothened.

(j) The image is rinsed with soapnut sud and brushed with a wire brush to remove the minute particles of emery sticking inside the details of ornaments and to *clean* it. After cleaning the figure is wiped dry with a clean cloth and made ready for polishing.

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*It is to be noted that the *Sthapathi* use the casting process merely for making a replica in metal of the wax model to be later worked over just like carving in stone. Hence, the finished image loses the beauty of modelling and looks like a carving in metal.

(k) Applying *polishing* soap, rouge (silversmiths rouge) and wiping with chamois leather brings out the full lustre of the image and gives it a satin finish.

Now, it remains for the finished image to be set up on a pedestal. Smaller images are cast with the pedestals and for bigger images it is more convenient to cast the image and its pedestal separately. For this purpose a part of the stem of the sprue and the vent are retained while pruning for threading and fixing the image on to the pedestal. The image is fixed on the pedestal and the balance is adjusted. The fixing is done so finely that even a keen eye cannot find out the joints. The image is now ready for display or installation.

Some of the tools and other materials used by craftsmen of Pondicherry, Thirupathi and Varanasi may also be mentioned in this centext.

The Pondicherry craftsmen use tamarind solution and ashes obtained by burning straw to rub and polish a metal image.

The craftsmen near Thirupathi in Andhra Pradesh use the following tools for chasing and engraving: tool for working out garlands and dress (*kolupo pogarā* — Telugu), tool for inlaying stars and dots (*summa pogarā* — Telugu), concave tool (*tāmara pogarā* — Telugu), convex tool (*valu pogarā* — Telugu), punches (*gubbogāṛā* — Telugu), rectangular headed tool (*vatti pogarā* — Telugu), diamond pointed tool (*gorū pogarā* — Telugu) and scraping chisel (*chivvelegā* or *chivve pogarā* — Telugu). Rubbing with a special variety of sea sand called *merugu isukā* (Telugu) which is obtained from a particular spot near Rayapuram beach in Madras provides a fine polish.

Some of the tools used by Varanasi craftsmen are: square headed tool (*chaurasiyā* — Hindi), dome headed tool (*gōla chaurasiyā* — Hindi), rectangular headed tool (*badāmā* — Hindi), concave tool (*powari* — Hindi), liner (*sūttanā* — Hindi), half round tool (*kadana* — Hindi) and diamond headed tool (*āgé muhā chaurasiyā* — Hindi).

Polishing is not done by the artisans who cast the image. This is done by Muslim craftsmen who first scrape the entire image and make it even. **N**ext they buff and polish it.

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4716.

ANALYSIS OF THE TRADITIONAL INDIAN TECHNIQUES, OLD AND CONTEMPORARY

The three texts, *Mānasollāsa*, *Śilparatna* and *Mānasāra*, touch on the subject of *cire perdue* casting in dealing with the use of metal images for *pūja* or worship. Hence, the authors of these texts have limited the technical information to the essential points of casting a metal image. Perhaps, it may also be due to the fact that the authors of these texts, being scholars, were not much conversant with the various technical details, pertaining to the subject. However, among the three texts the *Mānasollāsa* has provided more technical details than the rest. It describes the solid casting process and provides a fairly good information about the modelling, moulding, dewaxing and baking the mould, method for computing the amount of a particular metal required for casting according to the weight of the wax model, the temperature required for melting different metals, the melting process, casting and devesting. However, this text describes only solid casting. The *Śilparatna* omits many of the details provided in the *Mānasollāsa* but gives certain other information such as the different metals used for casting, their merits and demerits, the mode of obtaining and preparing the clay for moulding, core making in relation to hollow casting and shaping the crucible etc. The *Mānasāra* gives more emphasis on the religious aspects and provides very little information on the techniques involved.

The ancient Indian bronzes clearly show that our hereditary craftsmen were familiar with the various techniques involved in casting solid and hollow images in metal. However, these craftsmen have not left for posterity any technical literature on the subject. But this unwritten oral tradition has been passed on from one generation to another and down to this day. A study of the techniques used by our present-day traditional craftsmen in different parts of the country show that they have modified their methods according to the climate of the place, availability of raw material and tools. Their conservative outlook and lack of education have prompted them to confine their knowledge among their own kinsmen and prevented them from producing any technical literature.

In our analysis and comparative assessment, the subject has been divided under four broad heads: A. Modelling, B. Moulding, C. Casting, D. Finishing, which are further subdivided into various parts.

A. *Modelling*: (a) modelling media; (b) modelling tools; and (c) preparation of the wax model for solid and hollow casting. The wax model is weighed to calculate the ratio of different metals needed for casting in proportion to the weight of the wax model. Although it is not a part of modelling, it has to be done before the moulding.

B. *Moulding*: (a) places from where clay is procured; (b) moulding media and their preparation; and (c) method of moulding.

C. *Casting*: (a) foundry establishment for dewaxing, baking, casting and devesting; (b) dewaxing and baking the mould; (c) alloy for casting; (d) melting process and casting; and (e) devesting the mould.

D. *Finishing*:

A. *Modelling*

(a) Regarding the modelling media: All the three ancient texts mention that beeswax is used for making the wax model. Today, craftsmen in many parts of India prepare an amalgam consisting of beeswax, rosin and any of the non-freezing oils, such as sesame oil, mustard oil, groundnut oil, castor oil, margosa oil, kochara oil etc. In a few places charcoal powder of lampblack is added to change the dull yellow colour of beeswax into a darker shade for clarity of details while modelling. The addition of rosin lowers the melting point, increases the ductility which is helpful during the dewaxing of the mould. The mixing of non-freezing oils impart plasticity, softness and also removes the stickiness of the wax. This shows that the craftsmen have developed a medium suitable to their need.

(b) Regarding the tools used for modelling, the *Mānasollāsa* and the *Mānasāra* do not say anything about them. The *Śilparatna* mentions the use of tamarind wood, and bamboo for preparing the tools. Today the craftsmen use tamarind wood, ebony wood, sandal wood, bamboo, ivory, metals such as copper, brass and steel for preparing their tools.

(c) Regarding the preparation of a wax model: The *Mānasollāsa* describes the method of modelling a solid wax image according to the *Nava tala* measurement. The *Śilparatna* mentions the technique of modelling a wax model for hollow casting. The description given in the *Mānasāra* is not very clear. Probably modelling of a solid wax model is implied. None of these three texts gives any detail about the technique of shaping the different parts of a model. The present-day craftsmen practise both solid and hollow casting. In modelling a solid wax model they model the different parts separately. After, all the parts are ready they are attached to their appropriate places, retouched and merged with the contour of the figure. In case of hollow casting, wax sheets of even thickness equal to the cast intended in metal is carefully applied over a pre-prepared core and the details are worked out.

Regarding the fixing of sprue, vent and runners the *Mānasollāsa* alone mentions about the need for fixing a sprue in the shape of a *kāsa* or *hema puṣhpa* (flower) on the back or shoulders or neck or the crown of the wax model. But this text does not mention anything about vents and runners. Even with regard to the sprue the direction in which it is to be fixed is not clear but has to be presumed. The other two texts are silent regarding sprue, vent and runners.

Our present-day craftsmen use the gravity-cast system for their castings. In this process the gravity of the earth helps in the quick inflow of the melted metal inside the cavity of the dewaxed mould. While pouring, the air inside the mould is first pushed downward by the incoming metal and with the filling of the cavity it is pushed outside through the vent. Besides, this system helps to reduce the number of runners to feed the different areas of the cavity.

The craftsmen invariably fix the sprue and vent rods at the base of a wax model perpendicular to the feet or pedestal, running parallel to the main body of the image. While casting, the mould is kept with the head downwards and the sprue and vent holes facing upwards for feeding the metal. Generally, single sprue and vent are fixed, but in the case of complicated images like the Natarāja, more than one sprue and vent are fixed, in order to enable simultaneous feeding of metal inside the cavity of the mould and release of entrapped air. In case of hollow casting in addition to the fixing of the sprue, vent and runners, core pins are inserted through the wax surface into the body of the core at several points. These pins project a little beyond the wax surface and help to keep the core and the mould in position after dewaxing. This important information has been omitted in the *Śilparatna* which describes hollow casting.

Another important technical information is the method of ascertaining the amount of metal required for casting, in relation to the weight of the wax model. Only the *Mānasollāsa* deals with this point, which says that the wax model should be weighed before moulding. The present-day craftsmen follow two methods for computing the amount of metal required for casting. In the case of solid casting, the wax model is weighed before moulding and for hollow casting the core is weighed before applying the wax over it and is weighed again, after the modelling is done. The difference in weight shows the amount of wax used in modelling. As regards the ratio of different metals in proportion to the weight of the wax model, the *Mānasollāsa* alone provides the necessary information. It says that brass and copper should be eight or ten times, silver twelve times and gold sixteen times the weight of the wax model. But this text does not say anything about the necessity of having a little more metal than the actual amount required for casting in order to provide a margin for spillage etc.

The present-day craftsmen calculate their ratio, giving a margin for the above mentioned eventualities. Their ratio is as follows: Brass and copper ten times, silver fifteen times and gold twenty times.

B. *Moulding*

(a) Places from where clay is procured: Among the three texts, the *Śilparatna* alone provides information on this subject. It says that clay from holy places, mountains, gardens, holy lands and ant hills is suitable for this purpose. But it does not say why the clay from such places alone is suited for the work.

The present-day craftsmen procure clay from their neighbourhood. By long experience they could easily identify the one that suits their purpose well. In this connection it will be interesting to note that the choice of the locality differ from region to region. The *Sthapathis* of Swamimalai prefer the loam deposit from the river Kaveri. The craftsmen near Rajamundry in Andhra Pradesh collect the alluvial soil from the river Godavari during the floods. The Pondicherry craftsmen procure two varieties of clay, one saline and the other alkaline, from the lands around their village. The artisans of Thirupathi get clay from the sugarcane farms near their village. The bronze founders of Varanasi in Uttar Pradesh get their clay from a particular site on the banks of the rivulet Assi, which flows on the southern side of the city. The craftsmen in some parts of Orissa collect clay from paddy fields. The artisans of Jagdalpur in the Bastar district of Madhya Pradesh use clay from the banks of rivers, tanks or from ant hills. The Kəinkuya Mals of Bengal collect the loam from around the root studs of bamboo for the purpose. These show that the traditional Indian craftsmen have developed a crude scientific knowledge in identifying the clay that suits their purpose.

(b) Moulding media and their preparation: The *Mānasollāsa* and the *Śilparatna* mention the mixing of carbonaceous materials like charred rice husk, cowdung, cotton fibre or cloth for making the media with clay. In addition the *Mānasollāsa* mentions the use of fine salt (chemical additive) to clay. The *Mānasāra* does not mention anything on this subject. Regarding the method of preparing the moulding compound, the *Mānasollāsa* says that charred rice husk, severed cotton and a pinch of fine salt should be mixed together, over a stone slab. The *Śilparatna* is more explicit regarding the preparation of the clay compound. It mentions three types of clay compound for moulding, one for core making and a fifth type suitable for making crucible. They are described as hard, semi-hard, soft, very soft and crucible clay. It says that hard clay medium should be prepared by adding brick powder, arecanut husk juice and pure water to any one of the clays got from the sites stated before and pounding them together with pestle on a mortar. Cowdung when added to hard clay renders it semi-hard. Soft clay compound is made by mixing and grinding four parts of baked clay powder and one part of clay. For making very soft clay compound, cowdung is added to soft clay. Crucible clay is prepared by mixing pot clay with charred and powdered rice husk and finely sheared cotton cloth and pounding together with mortar and pestle. Hard clay, soft clay and very soft clay are used for moulding; semi-hard clay is employed for preparing the core and the crucible clay for making firm crucibles. It will be interesting to note that almost the same technique is still being used by the craftsmen in many parts of Kerala from where this text originated. The present-day craftsmen have added sand, jute cuttings and green grass to the list of additives mentioned in the texts. Besides, instead of charred rice husk they now use raw rice husk also.

(c) Method of moulding: The *Mānasollāsa* and the *Śilparatna* specify that three coats of clay should be applied successively over the wax model. Each coat has to be dried completely before the next is applied. The *Śilparatna* also mentions the use of iron bands for reinforcement. The present-day craftsmen apply three or four coats and reinforce the mould with iron bands. Each coat is allowed to dry before the next is applied.

C. *Casting*

(a) Regarding the foundry establishments for dewaxing, baking, casting and devesting, none of the three texts give the necessary information. The *Mānasollāsa* mentions the use of tongs for lifting the crucible and a sharp iron rod for punching a hole on it. When it says about the temperature required for melting different metals one has to assume that they have proper furnace for melting the metal. Similarly in the *Śilparatna* a dewaxing and baking oven is implied when it mentions about the use of a machine for fanning the flame and also a furnace for melting the metal. The *Mānasāra* is silent on this point. Today, the artisans use separate arrangements for dewaxing and baking the mould, a hearth for heating and breaking the scrap metal and furnace for melting the metal. Regarding the crucible for melting the metal, the *Mānasollāsa* mentions a clay crucible in the shape of a cocoanut with the metal encased inside it. The method of encasing the metal inside a clay crucible is still being followed by the craftsmen in Bengal, Rajasthan and Nepal. The *Śilparatna* and the *Mānasāra* do not say anything on this point. The craftsmen of today generally prefer to use a graphite crucible as it saves the trouble of shaping a clay crucible also because it withstands a number of melts. The three texts do not give any detail of the design of the dewaxing and baking ovens and of the furnace for melting the metal. The present-day craftsmen in different regions of the country have different designs of the oven and the furnace. The craftsmen in Kerala and Thirupathi in Andhra Pradesh use a combined oven-cum-melting furnace. But in other parts of the country they prefer to use a temporary hearth or forge for dewaxing. For baking they use a permanent oven. Generally a pit furnace is used for melting the metal. Hand bellows, hand blowers or electric blowers are used for blasting the flame. Among the foundry tools they have clip tongs, lifting tongs, pincers, skimmers, shanks, ladles and hammers. For devesting, cold chisels and hammers are used. Cowdung, cocoanut husk, wood, charcoal and coal are used as fuel.

(b) Regarding the method of dewaxing and baking the mould, the *Mānasollāsa* and the *Mānasāra* say that the mould should be heated to drain out the wax. The *Śilparatna* says that the mould should be placed over a wood fire and heated to drain the wax and to bake it until the inside gets the colour of a pumpkin flower. The craftsmen of today heat the mould either with cowdung, charcoal or cocoanut husk and redeem the wax in a pan containing cold water. They use one of these fuels for baking the mould. The mould is baked until the inside gets a glowing red colour.

(c) None of the three texts says anything regarding the alloy used for casting. Today most of the castings are done in brass, using scrap of unknown compositions. However, the *Sthapathis* of Swamimalai, the craftsmen at Thirupathi and Pondicherry have known compositions (refer pp. 17 and 18).

(d) Regarding the technique of melting the metal and casting, the *Mānasollāsa* alone mentions about the encasing of the chosen metal inside a crucible and shaping it in the form of a cocoanut. It also provides a rough calculation regarding the heat required for melting copper, brass (mild embers), silver (flaming embers) and gold (blazing embers). But the other two texts are silent on this point.

Regarding the setting of the baked mould for casting and the technique of pouring, the *Śilparatna* says that the baked mould should be placed inside a pit with the pouring cup facing upward. As regards pouring, the *Mānasollāsa* says that the crucible should be lifted out carefully with tongs, and a hole should be punched on it.* Similarly a lighted wick should be placed at the orifice of the pouring cup before the melted metal is poured into the mould. The *Śilparatna* says that the melted metal should be poured through the orifice of the mould, until it fills the cavity completely. The *Mānasāra* says that the metal preferred by the donor should be melted and the cast should be made.

The present-day craftsmen prepare the mould and the metal simultaneously for casting. Both clay as well as graphite crucibles are used for melting the metal. But the latter is invariably preferred because of its durability. Charcoal or coke is used for melting the metal. Most of the craftsmen prefer to use scrap metal for their castings. The metal is preheated, broken to pieces and then loaded inside the crucible. The Kainkuya Mals of Bankura in West Bengal, the craftsmen at Sawai Madhopur in Rajasthan and in some special cases the craftsmen at Varanasi adopt a technique in which the mould to be cast is fused with the crucible having the pouring cup facing the cavity of the loaded crucible. A small opening is left at the seam of the fusing line. Both are heated together in a furnace. From the colour of the fume that emits out through the hole, the craftsmen could determine that the metal is ready for pouring. The whole unit is then taken out from the furnace, a pinch of borax is introduced into the molten metal to clean it and the hole is sealed with clay and is turned upside down. The metal from the crucible flows into the mould and the casting is done. This method is used only for small castings where the mould and the loaded crucible can be lifted together without difficulty. In the regular process the loaded crucible is enclosed inside a down-draught furnace and the metal is melted. When the metal is getting ready the baked mould is carefully lifted with the lifting tongs deposited inside a pre-prepared pit, with the pouring cup facing upward and banked with sand or earth. The crucible is taken out from the furnace with clip tongs. Some borax (flux) is then thrown on the melted metal to clean it, the floating slags are removed and the metal is carefully poured into the cavity of the mould.

(e) Devesting is a simple process and the craftsmen still follow the one described in the texts.

D. *Finishing*

None of the three texts says anything regarding the various types of tools used for finishing. The artisans make use of an array of tools for different stages of finishing (refer pp. 18-20. The fine finish of many ancient Indian bronzes shows that the craftsmen of the past were familiar with various types of finishing tools and techniques.

Regarding the method of finishing: the *Mānasollāsa* says that the superfluous attachments should be removed by filing and the image be chased and finished. The *Śilparatna* says that the cast image should be chased and finished with various tools. The *Mānasāra* is silent regarding this point. The craftsmen of today make use of varieties of processes such as pruning, pickling, chiselling, filing, chasing, engraving, sanding, cleaning and polishing to finish a cast.

Only the *Mānasāra* mentions about the repair of a defective cast. It says that if there are minor defects the image should be repaired. But if the head or body is broken the image should be discarded and a fresh casting should be done. Presentday craftsmen repair minor defects by tapping in cold metal or by welding. But if the defect is a major one, they discard the cast and prepare a fresh model in wax and then cast it in metal. Because of the extreme care taken by the craftsmen, while moulding and casting an image, major defects very rarely occur.

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*Punching a hole on an enclosed crucible is still being followed by craftsmen in Nepal.

RELATED TRADITIONAL TECHNIQUES IN THE NEIGHBOURING COUNTRIES

The tradition of *cire perdue* casting in Nepal, Tibet, Ceylon, Burma and Siam have some distinct resemblance to that of Indian traditional process which might be possibly due to the ancient cultural contacts of India with those centres. Similarly, the bronzes from the ancient Indo-Chinese kingdoms and Indonesia show the influence of Indian culture.[1]

NEPAL

This Himalayan kingdom had been culturally a part of Indian sub-continent from very ancient times. Their two predominant faiths Hinduism and Buddhism are derived from India. Hence, the subjects used in their art forms are similar to Indian religious motifs.

The technique of *cire perdue* casting in Nepal is possibly an extension of the process followed by the Pāla craftsmen of Bengal and Bihar. Today, it is mainly carried out by the Newari craftsmen known as *Udāsa* (Newari) or *Bānādā* (Nepali) of Patȧn, a small township adjacent to the famous Pasupathinath temple in Kathmandu, the present capital of Nepal. The artisans have a caste title *Sākya*, and they trace their lineage to the royal clan of the Sakyas to which Lord Buddha belonged. The Sakyas profess Tantric Buddhism and serve also as priests in their community.

The Newari artisans are experts in stone and wood carving, coppersmithing and *cire perdue* casting. They claim that they use an ancient iconographic text in Newari known as *Yō Dekgō Sapuō* as guidance for their work which is similar to *Ṡilpa sastras* used by the *Sthapathis* of South India. But actually they carry on their work on the basis of practical experience. Unlike the *Sthapathis* who invariably make solid castings, the Newari artisans practise hollow casting. Only in the case of small images of less than six inches, solid castings are done. This process is divided into four principal stages.

A. *Modelling:* This is subdivided into: (a) modelling media; (b) modelling tools; and (c) preparation of a wax model. Before moulding, the wax model is weighed to ascertain the quantity of the metal required for casting in proportion to the weight of the wax model.

B. *Moulding*: This is subdivided into: (a) moulding media; (b) method of moulding and crucible making.

C. *Casting*: This is subdivided into: (a) foundry establishments for dewaxing, baking and casting; (b) dewaxing and baking the mould; (c) alloy for casting; (d) melting process and casting, and (e) devesting the mould.

D. *Finishing*: Finishing includes assembling the parts to make the whole, gilding and encrustation of precious and semi-precious stones.

A. *Modelling*

(a) The modelling medium is made up of a mixture of sixteen parts of beeswax *(moyin*—Newari*)* eight parts of additives like rosin (*rāla*—Newari*)* and one part of mustard oil. Small pieces of beeswax are melted in a brass or aluminium pan placed over a low flame of a charcoal brazier and powdered rosin is added to it and stirred well. Next mustard oil is added and stirred vigorously. The pan is removed from the fire and the compound is filtered through a fine muslin cloth and kept ready for modelling.

(b) The different tools and equipments used while modelling a wax model consist of a long wooden roller, a smooth marble slab, a wooden mallet, a compass, a calliper, horn modelling tools of various shapes, ivory modelling tools, steel knives, pincers and a small charcoal brazier.

(c) For preparing the wax model the craftsman first prepares wax sheets of uniform thickness. This is done by keeping a lump of wax compound on a marble slab; beating it with a mallet and then spreading it uniformly with a roller. He prepares a number of sheets and keeps them ready at hand for modelling.

Strips of wax sheets are cut according to the required size and rolled into hollow forms. While modelling the wax is warmed over the lighted brazier to make it soft for working with the tools. The different parts of an image are modelled separately and temporarily socketed to the main body. These socketing joints are located in such areas as to enable them to be concealed by modelling the ornaments over them.[2] In the case of neck it is covered by the necklace, at the wrists by bracelets etc. Subsequently, the parts are again taken apart for fixing sprues, vents and runners suited for gravity-cast system.

Next, in order to ascertain the quantity of metal required for casting the modelled parts are weighed and the amount is calculated in proportion to the wax used. In the case of brass it is ten times the weight of wax. The craftsmen have no clear idea regarding the ratio of silver and gold, as these metals are not used for casting nowadays. They, however, claim that they know the alloy for casting images in *pañchalōhā* (alloy of five metals) and *aśtadhātu* (alloy of eight metals).

B. *Moulding*

(a) The moulding media consists of: soft clay procured from a depth of fifteen feet from the fields, coarse clay dug from a depth of five feet from the fields, cowdung and rice husk. The soft clay and the cowdung are kept soaked in two different vessels overnight. Next day the cowdung is filtered through a muslin cloth and a thick solution is obtained. It is mixed with soft clay and a thin slurry is prepared for use in the first coat. Similarly, soaked coarse clay and rice husk are mixed and pounded with a wooden mallet. This dough-like mixture is used for the second coat.

(b) All the components of the wax model are moulded separately. Since they are hollow, both the inside (core) and outside moulding is done simultaneously. Care is taken to maintain a uniform thickness inside and outside which helps in the proper baking of the mould and prevents trapping of gas or air inside the core. Besides, it is also easy to remove the inner core after casting.

The first coat is applied in three layers and each layer is allowed to dry completely in the shade before the next is applied. After the first coat, core pins (iron nails) are inserted at suitable points to hold in position the core and the mould after dewaxing. This is followed by three layers of *second coat* carefully patted over the first coat. Each layer is allowed to dry completely before the next is applied. While moulding, the sprue heads are retained to facilitate dewaxing and the area is shaped like a cup. Reinforcements are very rarely used.

Shaping the clay crucible is described because it is done with the same type of coarse clay used for the second coat in moulding. The compound for shaping the crucible is prepared by mixing coarse clay and powdered rice husk. A clay crucible withstands only one melt. Hence a number of crucibles of different sizes are prepared and kept ready for use.

C. *Casting*

(a) The foundry establishments for dewaxing, baking, casting and devesting consist of: dewaxing and baking oven, melting furnace, dry earth and sand, a shallow pan or bowl, clay crucibles, a hand blower, lifting tongs, skimmer, clip tongs, pointed chisel (for devesting), hammer and charcoal.

(b) Small moulds are dewaxed by heating them over a charcoal brazier of the type used in modelling and the wax is collected in a pan containing cold water. The large ones are heated inside a specially made oven used for dewaxing and baking the mould. The dewaxing and baking oven of the Newari craftsmen is of a different design from that of the Indian artisans. It is built on the floor and is similar to wood-fired muffle furnace used for firing pottery. It consists of a hearth at the bottom and a chamber with a grilled floor over it. This chamber has an opening on one side for loading the moulds inside. Three or four openings each of a diameter of approximately two inches located equidistantly on the roof of the oven, serve as chimneys. After heating, the moulds are taken out and wax collected as in the above process.

After *dewaxing*, the moulds are given a fresh coat of fine clay mixture in order to seal off any crack that might have occurred while dewaxing. Then the moulds are once again arranged inside the oven and covered with charcoal. The opening is closed by two terracotta slabs and the baking is done.

The *baking* of the mould and melting of the metal go on simultaneously to get the mould prepared in time when the metal is ready for pouring.

(c) Broken brass and copper utensils are used for casting. Hence it is difficult to determine the exact composition of the alloy.

(d) The furnace used for melting the metal is of the same design as the baking oven. The scrap metal is preheated over a hearth broken into small pieces and loaded into clay crucibles. The mouths of the crucibles are closed with clay. A layer of charcoal is spread over the grilled floor of the furnace chamber and the crucibles are arranged over it. The space in between the crucibles are also packed with charcoal. The chamber is closed with the terracotta lids and fire ignited. Blasting is done with a hand blower and in between firing, the lids are opened and closed for adding fresh fuel inside. By experience, the craftsman knows the exact time when the moulds and the metal will be ready for casting. When ready he removes the moulds from the oven and arranges them with the pouring cup facing upward to receive the molten metal. The moulds are banked all around with sand and earth. When everything is set for pouring, the craftsman opens the furnace chamber and carefully takes out a crucible with tongs. He brings it near to the orifice of the pouring cup of the mould and punches a hole at the base of the cylindrical side so that the metal gushes out and flows inside the mould and quickly fills it. If the metal in one crucible is found insufficient, another crucible is quickly lifted out from the furnace and the content is emptied into the mould. After casting, the mould is left off to cool completely.

The melting of the metal inside sealed crucible prevents oxidation. Since the size of the crucibles is such that the work can be handled by two men without difficulty. As the castings are done in parts if there is shortage of metal during pouring, some moulds could be safely kept off for later casting. All these show that the Newari craftsmen by experience have devised ways and means to do their work easily and economically.

(e) After the moulds are completely cool, the external and internal clay is removed carefully with chisel and hammer and the cast is released.

D. *Finishing*

Finishing is done by adopting the various processes like pruning, pickling, chiselling tapping the core pins and blow holes, chasing and shaping, filing, scraping engraving, sanding, cleaning, fitting the different parts together, overall polishing, gilding and encrusting with precious and semi-precious stones. Most of these processes are similar to those of the Indian craftsmen. The different components of a figure are inserted at their respective places and skilfully rivetted. These joints are concealed with jewellery, encrusted with precious and semi-precious stones. Gilding is done with gold-leaf by applying it over an adhesive lacquer.

There exists, however, in Nepal a fundamental difference so far as the entire technique is concerned. In India every object, except the very big ones, is modelled, moulded and cast as a whole. In Nepal except for very small objects, each is done in separate parts (modelling, moulding and casting) and after casting the parts are assembled together.

TIBET

The technique of *cire perdue* casting followed in Tibet is similar to that of the Newari craftsmen of Nepal. Newari craftsmen claim that their forefathers took this art to Tibet.[3] In the Tibetan bronzes a hole is left in the cast to insert the magic formula printed on rolls of paper. After inserting the rolls the hole is sealed and the image is considered sacred.[4]

BURMA

The Burmese have always been expert founders especially of images, bells and fine gongs. The great bell weighing eighty tons cast for Bawdawyaya in 1790 is the second largest in the world.[5] The ancient bronzes from this country show the influence of the Pala art of Bengal.[6] Information available regarding the modelling medium and moulding compound is described.

The *modelling* medium is prepared by mixing two parts of beeswax and one part of rosin. The *moulding* compound for the first coat consists of clay and chopped straw. For the second coat ordinary clay is used.[7]

CEYLON

The traditional technique of *cire perdue* casting in Ceylon is an extension of the South Indian process where both solid and hollow castings are done.[8]

SIAM

Casting of bronze images and bells by *cire perdue* technique has been in vogue in Siam for nearly a millennium and a half. The technique has many similarities with that of India and Nepal. In Bangkok, there are many craftsmen practising this art.[9] The information available about hollow casting is being described. The whole process may be divided into four broad sections.

For *modelling* a wax model, a compound is prepared by mixing beeswax and shellac. Sheets are made out of this compound using a smooth board, teak wood roller and bamboo gauges for controlling the thickness of the sheets. Modelling is done with strips of wax sheets over a pre-prepared core shaped with a mixture of sand and clay. After modelling, core pins (nails) are inserted through the wax layer into the core and are allowed to project partly outside. Sprues, vents and runners are fixed and the wax model is made ready for moulding.

Two types of clay compounds are used for *moulding*. The clay compound for the first coat is prepared by mixing soft clay and cowdung. It is applied with a brush all over the wax model. Three layers of this clay are applied one over another and each layer is allowed to dry for an hour before the next one is applied. The compound for the second coat is prepared by mixing coarse clay and sand. This mixture is patted on with hand over the first coat to form a thick covering. Next the mould is reinforced with metal rods and is dried in the sun for several hours. While moulding, the tip of the sprues and vents are kept out without covering. The sprue head is shaped like a cup for pouring the metal.

For *casting*, the dewaxing and baking of the mould is done first in a brick-built beehive-shaped kiln. The wax is reclaimed in a pan for re-use later. The baking is done until the mould is ready for casting.

A religious service is performed by the master craftsman before doing the casting. He puts on clean white ceremonial clothes and does oblation to the spirits of his teachers with rice, bananas, cocoanut, meat, sugar, lighted incense sticks and candles. If a casting is taking place in a Buddhist monastery, Buddhist rites are followed before the craftsman begins his work. Scrap metal consisting of copper, brass, bronze, tin, lead and silver are used for casting. The metal is loaded inside clay crucibles and placed over the grate of a down-draught hearth. Usually, four crucibles are loaded at a time and charcoal is packed around the crucibles and fire is ignited. Fire is fanned with hand-operated bellows. When the metal gets ready, the bricks around the moulds are removed and the fire is put out. If there is any crack on the mould it is plugged up by patting with moist clay. Since the mould will be extremely hot, the workmen protect their hands and arms by wrapping water soaked cloth around them. Next, one by one the crucibles are lifted out of the hearth with the help of tongs, the molten metal is poured into the mould. After casting the mould is left to cool completely.

After the mould is cooled, it is broken off with the aid of chisel and hammer and the core also is removed. In some cases the core is retained, as it provides an excellent reinforcement for very thin casting.

Finishing is done by removing the extra attachments, filling the holes left by core nails and filing and rubbing with sand paper. This is followed by polishing and gilding with gold-leaf over an adhesive lacquer.

INDO-CHINA

Ancient bronzes from different parts of Indo-China have a distinct Indian touch. A wonderful hollow casting in bronze from this area is the bust of a thirteen feet statue of reclining Vishnu now in the National Museum at Phnom Penh, Combodia.[10]

According to an old treatise known as *Tamara devarup*, the Khemer artisans seem to have the secret of using an alloy known as *Samrit* or *thong tu'o'ng* (an alloy of nine metals consisting of nine parts gold, eight parts silver, seven parts copper, six parts zinc, five parts mercury, four parts tin, three parts iron, two parts bismuth and one part lead).[11]

INDONESIA

Cire perdue casting might have been known in Indonesia before the impact of Indian culture, it reached a peak of artistic excellence in this area following its contact with India. Most of the castings were done in brass. Beautiful metal objects including sculptures of fine workmanship of fairly early date have been discovered from widely apart regions of Indonesia.[12] Even today excellent castings are done in Batak district in Java, the Padang plateau in Sumatra, the coastal districts of south eastern Borneo and in the area around lake Matana in Celebes. Mostly articles of every-day use such as vessels, oil lamps, kettles etc. are made.[13]

The objects are *modelled* in wax over a clay core. Probably the sprue, vent and runners are fixed suitable for gravity-cast system. *Moulding* is done in clay. The alloy for casting consists of two parts of copper and one part of zinc. Finishing is done by chasing, embossing and engraving. Polishing is done with pumic stone.[14]

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TRADITIONAL TECHNIQUES IN CHINA AND JAPAN

The technique of *cire perdue* casting has a long and continuous history in China. Historically the earliest period of bronze casting by *cire perdue* process was during the *Shang* and the *Chou* dynasties, approximately covering the period between the middle of the second millennium B.C. to the middle of the first. During this period a vast number of bronze vessels were cast for religious, ceremonial and every-day use.[1] *Cire perdue* casting continued uninterrupted up to the end of Ch'ing dynasty (1911 A.D.).[2]

Information is available regarding hollow casting by two processes one direct and the other indirect. They are described below:

In the direct process, a *wax model is prepared* by applying wax sheets over a pre-prepared clay core, slightly smaller in size to the metal cast to be made.[3] After the modelling, moulding, casting and finishing are done as described in the previous chapters.

The second or indirect process is used for making a large number of reproductions in metal from an original in clay or wax or in any other media. The mould for *preparing the wax replica* comprises a number of sectional pieces and usually two covering moulds. The method is as follows:

The entire surface of the original is carefully studied in order to determine approximately the number of sectional pieces required to complete the mould and the size, shape and the seam of each piece. This is very important because the success of a piece mould depends on the precision of each sectional mould which can be pulled out easily from under-cut areas of the original model. These sectional moulds are provided with mortices and tenons* to interlock them perfectly with one another in order to have a complete mould when the pieces are assembled together. Next, the entire surface of the mould in pieces is again divided into two broad sections, to form two covering moulds (mother moulds or jackets). This helps to prevent the falling apart of the sectional moulds after they are pulled out from the original model and to hold them together for applying the wax inside for preparing the replica for *cire perdue* casting. The sectional moulds are carefully removed from the original and after soaking in water they are reset in their respective covering moulds. Then hot liquid wax is brushed inside the sectional moulds equivalent to the thickness of the cast intended in metal. The sectional moulds may also be treated with wax separately and then assembled inside their respective covering moulds and the seams are fused together. The covering moulds are then put together and firmly tied. The space between the seams may be filled in with hot wax. This is followed by the preparation of the core in the inner cavity. After the core is dry the covering and the sectional moulds are removed. The wax replica that comes out is retouched and got ready for moulding for *cire perdue* casting. For each casting the wax replica may be duplicated as required in the above process.

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*The discovery of many broken moulds with tenons and mortices in Hoiao-tun near An-Yang, gives rise to the hypothesis that indirect casting was practised. The seams that are found on many early bronzes strongly support this view.

The Chinese artisans seem to have used baked clay piece moulds for preparing the wax replica. After preparing the wax replica by the piece mould system, sprues, vents, runners[4] and core pins must have been fixed for their respective use though information to this effect is not available in relevant literature in English.

Moulding is done by applying successive layers of clay over the wax replica. The first layer is a thin diluted wash of clay which is allowed to dry. After that, further layers of clay are applied until the mould is sufficiently thick and strong. It is further strengthened with strips of clay on the outside.[5]

For *casting* the mould is heated to drain out the wax inside. It is further baked to stoneware hardness[6] and made ready for casting.

The ancient Chinese made successive attempts in perfecting the method of preparing their crucibles (Kan-Kuo) and standardising it. At first an ordinary straw-tempered tube-shaped clay crucible was used. It was replaced by an inverted bell-shaped coarse grittyware. The most advance type of crucible was provided with a double-layered wall, the space in between the walls being filled with fine sand. Such a crucible can withstand a very high temperature.[7]

A part of an ancient written record of the great code of state institutions under the Chou dynasty entitled *Chou li* has a section headed *K'ao Kung Chi*[8] which gives an estimate about the alloy used for different types of metal castings. The proportions of the various metals used are described below.

Five parts of copper and one part of tin for casting bells, cauldrons, gongs, sacrificial vases and utensils; four parts of copper and one part of tin for axes and hatchets; three parts of copper and one part of tin for halberd heads and trident spears; two parts of copper and one part of tin for straight edged swords which were made of two sizes according to the height of the bearer and for agricultural implements such as spade and hoes; three parts of copper and two parts of tin for arrowheads, employed in war and hunting and curved pointed knives; one part of copper and one part of tin for mirrors (plane and concave).[9]

The melted metal is poured through the pouring cup into the empty cavity of the mould and thus a casting of the wax replica is obtained.

The smooth surface that is noticed on the Chinese bronzes show that careful finishing was done over a cast.

JAPAN

Japan has a long history in *cire perdue* casting dating back to the Yoyoi period of c. 200 B.C. *Cire perdue* casting is known as *ro-gata* in Japanese. The tradition in *cire perdue* casting is still carried on by hereditary craftsmen.* The information on

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*There are two other processes known as *koma-gata* or *yaki-gata* and *so-gata* for metal casting. In both these cases wax model is not used.

hollow casting process as available is described. This description is about the casting of a brazier; the same method might have been used also for other types of castings. The whole process has been divided into four broad heads as: modelling, moulding, casting and finishing.

For *modelling* a wax model, a wooden framework having a number of flat strips with their external edges roughly cut to the shape of the interior of the object to be cast, is first prepared. Two wooden circular discs each in two segments having a hole at their centre are attached to the top and bottom of the frame by means of wires or cords. A wooden bar of suitable length is then passed through the two holes of the discs and the framework and attached to the discs with wedges. This bar helps to revolve the core while modelling. Thin strips of bamboo or cords of straw or both are bound round the exterior of the frame. Over the frame a clay mixture prepared with burnt and fresh clay and rice husk is applied in several layers. The exact form of the object to be cast is shaped during the final coating of clay mixed with sand. The core is allowed to dry completely,[10] and when ready modelling is done over it with wax sheets[11] of required thickness prepared with the help of a roller and a slab. After the modelling the sprues, vents, runners and drain are fixed and the wax model is made ready for moulding.

Moulding is done with three varieties of clay compound.[12] The clay preparation for the first coat is known as *kamitsuchi* (paper clay) which is prepared by mixing wet clay with sand. This mixture is made into balls and heated on charcoal or coke until they turn red. They are then broken and sieved through a fine mesh and the powder thus obtained is mixed with clay, old paper or wool or chopped cotton. In olden days horse dung was also used for this purpose. This liquid clay compound is carefully applied over the wax model with a brush. Several layers of this clay are applied and each one is allowed to dry before the next application. Thus this coat is made sufficiently thick. Over the first coat a second composition known as *tamatsuchi* prepared with medium sand and clay solution (red clay and seven to eight parts of water) is applied and dried. This is followed by a third coat known as *aratsuchi* prepared by mixing coarse sand, straw, wood chip and kneading it properly. Along with this two pouring cups are also shaped one at the lower and the other at the upper level. The mould is allowed to dry slowly in a warm place in the foundry and when dry the wooden frame is removed.

For *casting* first the dewaxing of the mould is done by placing it over a regulated charcoal fire, taking care to heat the hollow core and the outside of the mould evenly. Heating is done until wax is melted out and all traces of moisture are expelled from the mould.

For baking the mould is supported over five or six bricks in order to have a hearth below it. The holes of the pouring cups are closed with clay stoppers to prevent any fuel from getting into the cavity of the mould. A wall of fireclay slabs is built around the mould. The slabs are kept in position with hoops and bands and a minimum gap of three inches is left between the wall and the mould. A charcoal fire is made in the hearth below the mould. The space between the mould and the wall is also filled with burning charcoal mixed with broken bricks and crucibles to prevent the heat from becoming too intense. The interior of the core is also partly filled with the same mixture. The mould is heated until it turns red hot. When the mould is ready for casting, the wall of fireclay slabs is dismantled and the hole through which the wax drained out is closed with fireclay. The mould is taken down from the bricks and made ready for casting by supporting it with piles of large stones around its base. The stoppers inside the pouring cups are removed. The mould is now ready to receive the liquefied metal.

Simultaneously with the baking of the mould the metal is also prepared for casting.

The alloy (*karakane* which means Chinese metal introduced into Japan from China) is used for casting art objects. It contains approximately eighty eight per cent copper, two per cent tin, three per cent zinc and seven per cent lead. However, the Japanese craftsmen generally prefer to use scrap metal for their casting similar to Indian traditional craftsmen.

An ingeniously built cupola furnace is used for melting the metal, the bottom of which forms the hearth. It has two openings, one for tapping the metal and the other for the insertion of a tube for blasting the flame. The cupola is shaped with cylindrical fire bricks or slabs cemented together with fireclay and firmly bound round with iron bands. It is erected by placing the hearth segment on an approximately one foot high brick platform so that the tap-hole can be at a convenient height for tapping the metal. Melting is done with charcoal fuel and blasting is done with the help of manually operated *tatara* (bellows). When the metal gets ready it is tapped into iron ladles equipped with parallel pole handles.[13] The workmen take position opposite the ingates of the mould and when signalled pour the melted metal into the mould. As the metal reaches the top of the lower ingate it is closed with stopper of fireclay. Pouring is continued through the upper gate until the entire cavity of the mould is filled. After casting the mould is left to cool for several hours and before devesting, it is cooled by pouring water over it. The mould and the core are removed and the cast is released.

Since the casting contains very few attachments finishing is easy. It is done with the help of files, scrapers and cold chisels.

A master piece of Japanese *cire perdue* casting is the world famous image of Buddha in bronze in the temple of Todaiji monastery at Kamakura in Japan. The height of the image is 53 feet and it weighs nearly one million pounds.[14] The moulding and casting of this image were performed in sections. After each section was cast they were brazed together and the outer surface was smoothly finished to provide a perfect contour. In the hollow interior the joints can be seen. The work of casting this great image was started in A.D. 743 and was completed in A.D. 749. It seems the casting of the whole figure alone took two years from A.D. 747 to A.D. 749. The extant record states that seven tons of wax as well as seven tons of coal were used for modelling and as fuel.[15]

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TRADITIONAL TECHNIQUES IN OTHER OLD CIVILISATIONS

ANCIENT EGYPT

The ancient people of Egypt, who were experts in various crafts, knew the technique of solid and hollow *cire perdue* casting. Besides, they were familiar with the method of casting part by part and fitting them together by means of mortices and tenons.[1]

For solid casting, they *modelled* the figure in beeswax alone and for hollow casting they did the modelling in wax applied over a pre-shaped core. The core was made with a compound of quartz sand mixed with a small proportion of organic material.

The *moulding* was done in two coats. The first one was made with a mixture of alluvial clay from the Nile river, chopped straw and dung of donkey.[2] The second outer coat was made with sand or earth. These details are obtained from the analysis of a mould of twelfth century B.C. from Kuhan.[3]

After dewaxing and baking the mould, *casting* was done in the usual manner. They seem to have used an alloy consisting of seventy six to eighty parts of copper, eleven to twelve parts of lead and three to eleven parts of tin.[4] Their foundry equipments consisted of an open hearth, crucibles made with a mixture of sand, clay and crushed quartz, feet-operated bellows and a long rod. This information is available from a wall painting in the tomb of Rekhmire vizier of upper Egypt during the reign of Amenhotep II in c. 1140. B.C. The paintings show two men working bellows and another turning the embers with a rod.[5] The use of open hearth for melting the metal prevented them from making big castings.[6]

Finishing was done with the aid of chisels.[7] In the case of hollow casting, generally the inner core was left in. A good example of hollow casting of the Egyptians is the bronze head of Rameses II, now in the British museum.[8]

ANCIENT MESOPOTAMIA

Cire perdue casting seems to have been in vogue in this area of the world even early in 3rd millennium B.C. and was continued in the subsequent ages. Both solid and hollow castings were practised.

The figures were *modelled* in beeswax[9] and *moulded* in clay.[10] *Castings* were done both in copper and bronze.[11]

ANCIENT GREECE

The credit of inventing the technique of *cire perdue* casting in ancient Greece goes to two artists named Rhoikos and Theodoros of the island of Samos.[12] This island was ruled by the tyrant Polykrates who had close commercial relations with

Egypt.[13] Hence it is not clear whether Rhoikos and Theodoros were the real inventors or learned the technique from outside, since casting in metal was known to the Egyptians and the Assyrians long before the Greeks knew it.[14]

The Greek practised both solid and hollow casting. For hollow casting they used both the direct and indirect processes. They also knew the technique of casting part by part and putting the parts together with mortices and tenons. An Athenian cup in Berlin depicts the scene of a foundry showing the assembling and finishing of two bronze statues of large size.[15]

Beeswax was used for *modelling* the figures.[16] Solid casting was used for small statuettes. For hollow casting by the direct method they applied wax over a pre-shaped core made by mixing sand and some organic materials. Polykleitos a well known sculptor of the classical period seems to have used the piece mould process[17] for preparing bronze castings from his originals in clay. This is judged from his well known writings. First a clay model is made corresponding exactly to the required statue and finished on the surface. Over this is placed the mould. Then the mould is taken to pieces and the original clay model is taken out. A coat of wax of the required thickness is then applied to the inside of the mould and the rest is filled with fire proof material to form the core. Then the wax is melted out and the metal poured in. Possibly the method of preparing the piece mould might have been somewhat similar to the method described in Chapter V. It is presumed that the Greeks developed the technique of hollow casting from the *repousse* work which was done by hammering out images with sheet metal over a wooden carved figure (*xona*). They found that it is possible to prepare moulds from the wooden core and make hollow castings.[18] An examination of the large sixth century Greek bronzes seem to suggest that they were not cast by means of *cire perdue* process, but were cast into two-piece sand moulds made from wooden originals. A core of casting clay was placed into the two-piece mould before pouring the molten bronze.[19]

Moulding was done with a mixture composed of pounded brick, clay, ash, sand and organic matter in two coats. The first coating was applied in several layers with a mixture of pounded brick, clay and ash ground in water. A thick second or outer coat was done with soft clay.

For *casting*, the mould was heated in an oven for dewaxing and baking. The metal was melted in a shaft furnace[20] and casting was done as usual. An analysis of the bronzes shows that the Greeks used an alloy of eighty nine per cent copper, six per cent tin and five per cent lead for casting.[21]

The work of chasing and *finishing* which was known as *toreutike*[22] was very important among the Greek sculptors. They keep their statues in natural golden yellow colour.[23]

ANCIENT ROME

The technique used by the Romans for *cire perdue* casting was a continuation of the Greek process and the sculptors and founders working in Rome were mostly of Greek origin

SOUTH AMERICA
(Incas, Aztecs and Maya)

Craftsmen among the Incas, the Aztecs and the Maya knew the technique of solid and hollow casting. This information comes to us from the Spanish writers who lived between A.D. 1500 and 1800. Releigh (A.D. 1596) a writer of this period gives us a brief account of casting as carried out by the Aztecs[24] which was also the one used in Columbia and Peru. The technique reached its highest development in Oaxaca area in Mexico during 15th and 16th centuries.

The *modelling* compound was prepared by mixing beeswax *(cere de campeche*—Spanish) and copal gum.[25] After modelling a figure, the sprue and vent were fixed at the base and runners were attached at suitable places. A pouring cup was fixed at the end of the sprue.

Moulding was done in two coats: the first one was made with charcoal mixed in water. The Aztecs termed it *teculatl*[26] which literally means coal water. The second coat consisted of a mixture of moist clay and crushed charcoal. The entire figure except the tips of the sprue and vent were covered with this mixture. A pouring cup was formed at the tip of the sprue. The mould was strengthened by packing around with further application of clay. The core for a hollow casting was prepared by mixing clay and crushed charcoal. Cactus thorns or wooden nails were used as core pins.

Dewaxing was done by keeping the mould with the pouring cup facing downward over a hearth and after the wax was drained out, the mould was reversed with the pouring cup facing upward for baking and getting it ready for casting.

Casting was done in gold, silver, copper and with an alloy called *tumbaya*.[27]

The metal was melted in a charcoal-fired open air foundry. The crucible was made by dubbing and drying a mixture of clay and charcoal over a piece of cloth. They used a manual device to blast the flame. Men blew air through copper or reed tubes: eight to twelve such tubes were put together in such a way that the opposite openings of the tubes met at a single point. The air coming from the tube was channelled at this point to enter the furnace through a single opening to blast the flame. When the metal was ready casting was done as usual.

Finishing was done with disc-shaped tools prepared with an alloy of copper and brass. The craftsmen held these tools in their hands and used them as if they were pebbles. They had no knowledge of files or grooving tools.[28]

AFRICAN KINGDOMS

Before the influx of the Europeans into Africa a civilisation flourished in Nigeria which produced remarkable bronzes. The kingdoms of Benin, Yorubaland and the land of Ife are famous for their bronzes. Artistically the most impressive remains of these vanished kingdoms are the portrait heads. The castings were all done by the *cire perdue* process.[29]

The craftsmen practised hollow casting. For preparing a wax model, the core was prepared by mixing fireclay and charcoal. This mixture was used because it withstood the great heat released by the molten metal and also absorbs the gas generated inside the mould while the hot metal enters the cavity. After the core was dry wax coils were wound around the entire surface of the core and it was worked over with the help of a spatula. The details were worked out and the model was finished. Core pins made from iron rods were inserted at suitable points for the purpose of linking the core and the outer mould. Sprue and vents were made with wax rods and the free end of the sprue was shaped like a cup.

Moulding was done in two coats. The first coating was applied with fireclay slip which covered every minute details of the wax surface. After it was dry successive layers of coarser mixture of fireclay (ant hill clay)[30] mixed with finely chopped goats hair, was applied until the mould got a thickness of about three-fourth of an inch. Great care was taken to dry the mould without forming any crack.

For *casting* the mould was dewaxed by heating it in wood fire. It was further heated and made ready for casting. When ready the mould was buried in a heap of sand or a pit in the earth for casting.

Simultaneously with the baking of the mould, the metal was prepared in a crucible. The furnace was worked with charcoal fire and the blasting was done with the aid of manually operated bellows. The craftsmen depended upon their experience to judge correctly the right moment for pouring the metal inside the mould. When the metal was ready, the crucible was lifted out carefully and the metal was poured into the cavity of the mould and filled. By experience they knew the exact amount of metal required for a particular coating and their judgement rarely went wrong. After the coating, the mould was left to cool down completely. When cool it was broken and the cast was released.

Very little chasing and finishing were done over the cast image, except the cutting of the sprue and vents. After that the image was cleaned and polished.[31]

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MODERN TECHNIQUES IN THE WEST

The great advances in the techniques of *cire perdue* casting which we find today in the west can be traced back to the changes that were happening there since the Renaissance. A great revival in every aspect of human knowledge was evident in Italy during the Renaissance age. Its impact was felt on all forms of art and the study of the classical traditions of the Greek and Roman world was revived. There was a renewed activity in metal casting which was indicated by the number of experiments done in respect of its methods and materials. Both direct and indirect processes of hollow casting were practised and the information available about them is described.

I. CIRE PERDUE CASTING DURING THE RENAISSANCE AGE

Benvenuto Cellini a well known sculptor of this age had left the following account of the technique used by him for the direct process of *cire perdue* casting.

For *modelling* in wax, a clay core, slightly smaller in all its contours was first prepared over an iron armature and was well baked. Over this the figure was modelled in wax. Long metal pins were inserted through the wax surface into the core at various points to serve as core pins. Sprues, runners and vents were fixed for their respective use.

Moulding was done by two successive coatings. The ingredients for the *first coat* consisted of four parts of *gesso* (Italian-Latin-Plaster of Paris) of Tripoli, two parts burnt ox-horn cores or bones, one part of iron filings and a thick liquid of horse or cowdung. The liquid was prepared by mixing the dung in water and passing it through a sieve. The first three ingredients were finely ground together and then mixed with the thick dung liquid. It was applied all over the surface with a big sable hair brush. Three layers of this clay were applied and each layer was allowed to dry before the next application.

The ingredients for the *second coat* consisted of two parts of clay (clay obtained from the hills or grottoes near Rome or Florence) and one part of cloth shearing. The clay was first dried and sifted through a coarse sieve and the hard particles were removed. Next, cloth shearings were added to the clay, mixed with little water and beaten with iron rod to make it into a dough. The mixture was allowed to decompose for about four months before it was used. Two layers each measuring half an inch in thickness were applied over the first coat. The first layer was allowed to dry before the next was applied.[1] The mould was reinforced with iron bands.

For *casting* the mould was first heated over an oven to drain out the wax inside. After that it was enclosed within a brick fence and baked with firewood.[2] When properly baked, it was lifted and deposited inside a pit and kept ready for casting.

Bronze was used for casting. It was melted in a woodfired furnace and before pouring some pewter was thrown into it for fluxing. After that it was poured into the mould with the help of a shank (mandriani—Italian) and the cast was left to cool for two days bofore devesting. The cast seems to have passed through skilful finishing before final presentation, which is evident from the excellent surface noticed on Renaissance bronzes.

For the indirect process, the sculptor first modelled his figure in clay and then a plaster piece mould of the same was prepared. No information is available to say whether the piece mould was obtained directly from the clay original or from a plaster copy prepared through the waste mould process as is done today. It has to be inferred that the waste mould technique might have been used as it is normally difficult to prepare a piece mould directly from a clay model. After the piece mould was ready, each section of it was given a thick coating of hot wax inside equal to the thickness of the cast to be made in metal. The sections of the piece mould were re-assembled and the inside was filled with core material and reinforced with iron rods. Next, the plaster piece mould was removed, the wax surface was retouched, sprues, runners and vents were fixed.* Although no information about the fixing of core pins is available, probably it might have been used before moulding was done. When the mould was dry it was heated over an oven and the wax melted out and the cavity left by the wax was replaced with metal.[3]

II. MODIFIED TECHNIQUE

The modern method in *cire perdue* casting may be recognised to be a modification of the Renaissance technique. This modified method is predominantly followed in Italy and has spread to other European countries and to North and South America through the migrating Italian craftsmen. This method may be divided into four principal stages.

A. *Modelling*: This is subdivided into: (a) modelling media; (b) modelling tools; (c) preparing a wax model in the direct and indirect processs. In the indirect process the wax replica of a clay model is prepared by following a method which involves the making of a plaster copy of the model in between. In this process have the moulding comes in, but this moulding is not to be confused with moulding of the wax replica for eventual casting in metal. Weighing of wax model or replica to ascertain the ratio of the metal used for casting.

B. *Moulding*: This is subdivided into: (a) moulding media and (b) method of moulding — hand building process and the pouring process.

C. *Casting*: This is subdivided into: (a) foundry establishments for burn-out process (dewaxing and baking), casting and devesting ; (b) burn-out process;

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*No information is available as to how the weight of wax used for preparing a replica was ascertained in order to calculate the amount of metal required for casting. This can easily be done by weighing the amount of wax to be melted for applying inside the mould and deducting the amount of wax left over after the work is done. A slight margin may be given for the amount that will be lost during the process of work. The difference will show the amount used.

(c) alloy for casting: (d) melting process and casting; and (e) devesting the mould.

D. *Finishing*: This is subdivided into: (a) pruning; (b) pickling; (c) tapping the blow holes; (d) filing and grinding; (e) chasing and matting; (f) sanding; (g) polishing and buffing; (h) cleaning and (i) patination.

A. *Modelling*

(a) The modelling media for preparing an original for *cire perdue* casting are beeswax compound and clay. Beeswax compound is used for preparing an original in the direct process and for preparing a wax replica in the indirect process. Clay is used for preparing the original in the indirect process. Both these processes are the same as described earlier.

The beeswax compound consists of beeswax with additives such as burgundy pitch, carnauba wax, ceresin wax, cocoa butter, halowax, lanolin, lead linoleate, lead oleate, paraffin, petroleum jelly, rosin, tallow, venice turpentine, olive oil and calcium carbonate. Many kinds of compounds are prepared by adding one or more of the above additives and the formulas of some of the compounds are given below:

Compound for modelling solid statuettes: sixteen parts of beeswax and one part of lead oleate.

Soft wax compound: sixteen parts of beeswax, one part of lanolin, one part of lead oleate, sixteen parts of paraffin and one part of venice turpentine.[4]

Dipping wax: two parts of beeswax, four parts of paraffin, five parts of ceresin, four parts of carnauba wax, and two parts of holowax.[5]

Mixture for undercoats: one part of beeswax, one part of rosin and one part of paraffin wax.

Semi-hard compound: (i) four parts of beeswax and one part of venice turpentine;[6] (ii) one part of beeswax, one part of rosin, nine parts of calcium carbonate and olive oil.[7]

For preparing the compound the beeswax is melted in a double boiler and heated over a very low fire and other ingredients are added one after another. When all the ingredients melt the amalgam is strained through a clean, fine mesh cloth.

The clay used for modelling an original for the indirect process is a special variety dug out from natural deposits under the earth. This clay is dried thoroughly, the lumps are broken and crushed down to small particles and sifted through a fine mesh. The powder thus made is thoroughly soaked in water and kept away for a few days. When ready it is kneaded and made suitable for modelling. A well prepared modelling clay is soft and moist but not sticky.

(b) Modelling tools are prepared from lignum vitae wood and aluminium. They are shaped according to individual needs. Wooden tools are dipped in melted paraffin wax or treated with oil. Metal tools are also made from old dental or surgical instruments. A gas burner is used to heat the tools while modelling.

(c) For making a wax model, wax sheets are prepared by pouring melted wax inside soaked plaster cases and when set they are removed and stocked for use. Similarly wax rods of different girths are prepared with plaster cases.

In the United States a number of art supply firms stock wax sheets, rods, pouring cup and even pre-shaped wax forms for the convenience of the sculptor.

Two methods are used for modelling a wax model. They are the direct process and the indirect process mentioned earlier.

In the direct process both solid and hollow wax models are prepared. Solid forms are modelled with wax and hollow forms are modelled over a pre-prepared core or by dipping the core in molten wax compound. Another method is to shape hollow forms with wax sheets.

The indirect process is used for preparing several wax reproductions from a clay original in order to prepare a number of copies of the same sculpture. In this a plaster copy is obtained from the waste mould prepared from the clay original. Next, a plaster piece mould is prepared from the plaster copy for preparing the wax replica.

A waste mould from a clay original is usually made in two pieces, but occasionally when needed it is composed in more than two pieces. Initially the clay original is carefully studied and the parting line of each piece of the waste mould is determined and marked on the clay model. Clay band or shim brass or cut film fence of about one inch width is built along the seam lines and around it. Moulding is done with two different coatings of plaster. The first is a yellow ochre mixed plaster coat and the second one is without ochre. A creamy mixture of ochre and plaster of Paris in water is carefully applied over the portion of the model to be moulded either with a fine camel hair brush or by splashing. Care is taken to fill in the intricate details and to prevent the formation of air bubbles. As the plaster sets hard, a thin coat of clay water is applied over it to prevent the second coat of plaster from adhering to the first one. The second coat is next applied and the total thickness of the mould is built up to one inch or more as required. Reinforcement is made with iron rods or cotton waste or burlap cuttings. After the second coat sets the fence wall is removed. Two types of notches are cut out to serve as keys to hold fast the contiguous sections of the mould after removal from the clay figure. The notches at the edge will be V-shaped and those on the side are concave. The other areas are moulded in a similar fashion. Then sectional moulds are separated from the clay figure by driving wedges between the joints. When a small gap is formed water is poured through them to loosen the clay inside. The moulds are pulled out carefully. The clay particles sticking inside them are removed and the moulds are thoroughly washed in water lathered with diluted soap oil emulsion, until the surface shines. Excess soap sticking inside deep areas is removed with a soft brush. The waste mould is now ready for preparing the plaster copy.

A thin layer of plaster is applied inside all the sections of the mould and is strengthened with burlap cuttings or cotton waste. The edges of the moulds are cleaned of the dripping plaster and are put together and tied firmly with rope. The outside joints are sealed by applying liquid plaster. The inside is further strengthened with additional coats of plaster and sometimes reinforced with iron rods. After it has set the mould is chipped off with a blunt chisel and mallet. Since this mould is wasted by chipping off it is called the 'waste mould.' Initially the second coat and the reinforcements are removed exposing the colour coat inside which indicates the proximity of the plaster copy. The colour coat is removed carefully and the copy is released. Retouching and finishing are done and the plaster copy is ready for piece moulding.

From the plaster copy obtained by the waste mould process a *piece mould* is made. Since this whole mould consists of several sections or 'pieces' it is called a 'piece mould'. The pieces are determined on the basis of the undercuts, which is a term used to describe the projections on a model that are behind and beyond the visible parts of the figure. The pieces are so fashioned that they can be removed without damaging the plaster copy or the mould.

There are various ways for making a piece mould. Choice of a particular method depends upon the nature of the figure to be moulded. In the case of a large standing human figure with projecting parts such as arms, legs etc., they are sectioned from the main body and moulded separately. For example the arm may be cut near to the elbow and leg may be sectioned at the thigh. One end of the cut face is provided with tenon and the other with a mortice in order to assemble them together after a metal cast is made to complete the figure. The most common piece moulding method is described below:

Before starting the work, the plaster copy is given two or three coats of fine solution of shellac or lacquer or varnish to seal off the pores and to create a sleek surface. This also prevents the sectional pieces that come into contact with the surface of the plaster copy from adhering to it. After this the plaster positive is laid horizontally over a smooth board, balancing it with a clay support which forms a rim of about two inches all around the figure dividing the plaster copy into two halves horizontally. This exposes one half of the plaster copy for moulding, leaving the other half embedded in clay.

Three types of sectional pieces are used to complete a piece mould. They are: small pieces; sectional pieces and covering pieces. The smaller pieces are used to mould the undercut areas. A single piece is made by applying plaster of Paris of cream-like consistency with a tuft like projection of the top. When set, it is carefully removed by deftly tapping the tuft. The tuft is cut off and the dome shape is perfected with a sharp knife taking care not to form any undercuts and re-set in its place on the plaster copy. Concave notches are made on the top to serve as keys for holding the small piece on the sectional piece which will be moulded over it. Sometimes a wire loop is fixed on the dome surface. Later this loop serves to prevent the sliding down or falling apart of the small piece, while reversing and fitting the two halves of the covering mould. The surface is given a coat of soap oil emulsion to prevent the sectional piece from adhering to the small piece. All the small pieces are moulded in this manner.

For preparing a sectional piece, an enclosure is made with clay strips of one inch width. These clay strips are placed in such a way as to avoid the formation of undercuts. If there is a small piece with a wire loop within this enclosure the loop is kept upright and covered with a layer of clay. A hole is formed by removing the clay after the sectional mould is done. This arrangement extends on to the surface of the covering mould. Liquid plaster of creamy consistency is filled into the enclosure and the surface is made slightly convex, smoothened and allowed to set. Sometimes the wire loop arrangement is made on the surface of the sectional mould also. After the sectional mould sets the clay walls are removed, the edges and the sides are perfected with a sharp knife and V-shaped notches are cut on the edges. Similarly concave notches are carved on the side walls and on the top surface to serve the same purpose as stated earlier. The sides and top of the sectional piece are brushed with soap oil emulsion. Thus the entire surface of the plaster positive is covered with sectional piece moulds. Next, a clay wall equal to the thickness of the covering mould is formed around the rim of the clay base. Liquid plaster is filled into the enclosure. The mould is strengthened with burlap cuttings and iron rods and proper care is taken to avoid covering the clay projections coming from the loop on the surface of the small and sectional moulds. A few leg-like projections are raised on the top and levelled perfectly by pressing over with a smooth, oiled wooden board. Back side mould is done in the similar way after reversing and removing the clay support and providing the proper key system as done earlier. When the moulds of both the sides are ready, the covering moulds are removed, the sectional pieces are taken out, numbered on their back and on the area of contact and re-set on the respective covering moulds. Similarly the small pieces are removed, numbered and re-set on their areas of contact on their respective sectional mould. While resetting a sectional or small mould with a loop on the back, the clay cover on it is removed. A cord is passed through it and brought to the surface of the covering mould through the hole provided for it on the sectional and covering moulds. At the rear end of the cord, a small stick is tied and turned until the piece is firmly held.

Now the piece mould is ready for preparing the wax replica. It is thoroughly soaked in hot water* and hot liquid wax is painted inside to the thickness of the cast required in metal. After each application of wax, cold water is sprayed over to harden it. Followed by the application of wax on both halves, they are put together and tied firmly with a rope which passes in between the leg-like projections mentioned earlier. Some liquid wax is poured inside the mould to seal the joints. The wax applied is allowed to set hard. Next, the core material is filled inside the cavity and allowed to set. Then the piece mould is removed and the wax replica is released. If required the surface of the replica is retouched, sprue, vents, runners, drains and pouring cup are fixed and the moulding is done for *cire perdue* casting. Usually the piece moulding is done by expert moulders. After the wax replica is ready, the sculptor steps in to do the retouching and affixing his name. The rest of the job like fixing the sprue, vents, runners, drains and pouring cup and moulding for *cire perdue* casting are done by expert founders.

The plaster piece mould method was replaced by the flexible mould method, as it was found to be more versatile compared to the former. A mould prepared with flexible and elastic media is called a *flexible mould*. It consists of two parts. A mould in a flexible medium such as gelatine or rubber and a casting termed as covering mould, made of plaster of Paris, to hold the mould. Usually the whole mould is divided into a front and a back sections.

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*Soaking the mould in hot water prevents ripple marks. Rapid drying of the mould is prevented by drenching the mould with cold water. This helps the wax replica to come off easily.

A flexible mould possesses certain distinct advantages over the plaster piece mould as it eliminates the need for dividing the mould into many parts. This mould being elastic regains its shape again when pulled out from undercut areas. Gelatine, latex rubber and synthetic rubber compounds are used for this purpose. The choice of a particular medium depends on the nature of the work at hand, the availability and the cost involved. The overall technique used for preparing a flexible mould with these materials is almost the same except for the difference in the components and their preparation.

Gelatine mould, which came into use in 1865[8], is sometimes referred as glue mould. But glue is actually an impure and cheaper variety of gelatine and does not possess much elasticity.

Gelatine is organic in nature which is soluble in hot water. It is supplied in the form of sheets or flakes and the finest quality of gelatine is used for preparing flexible moulds. The superior grades contain less impurities and possess greater water-absorbing property.

There are several formulas for the preparation of a gelatine compound for flexible mould. Some of them are given below:

(i) Four parts of carpenter's glue, four parts of gelatine, seven parts of glycerine, five parts of water and four parts of cotton seed oil. The glue and gelatine are kept soaked in water for twelve hours. When they become soft they are transferred to a double boiler and heated until they dissolve to form a syrupy liquid. Glycerine and cotton seed oil are then added and stirred and allowed to cool to body temperature before use. The temperature is tested by dipping a moistened finger into the compound.[9]

(ii) Four parts of carpenter's glue, one part of water and one part of glycerine. The glue is soaked in water for a day and glycerine is added. This mixture is heated over a low flame until the total mass is reduced to one sixth of the total mass.[10]

(iii) Eight parts of gelatine, seven parts of molasses. The gelatine is soaked in water for about twelve hours, the excess water is poured off and the mass is heated carefully over a low flame. The molasses is heated to boiling point and added to the hot gelatine and the mixture in briskly stirred.[11]

(iv) Three parts of edible gelatine, three parts of cold water and three parts of ethylene glycol. The three ingredients are put in a double boiler and heated over a low flame. Occasionally the mixture is stirred until the gelatine dissolves. Heating is continued till a clear bubble-free translucent viscous liquid is formed. The froth on the top is skimmed off and the mixture is ready for use.[12]

For preparing a flexible gelatine mould, the plaster copy is treated in the same manner to seal off the pores as stated for piece mould. The plaster copy is also balanced and divided into two halves horizontally, as stated earlier. A clay sheet of about half to one inch thickness having an overall area which is a little more than the surface to be covered in the plaster copy is prepared on a smooth board dusted with French chalk. It is carefully lifted and placed over the exposed area of the plaster copy and pressed following the form as closely as possible. This clay sheet extends over the clay rim dusted with French chalk to prevent its adhering to the clay sheet. Care is taken to keep the sheet thicker near the seams of the two sections of the mould. Next, several conical clay rolls are fixed upright to the clay sheet at some elevated points on its surface. Similarly a larger funnel shaped clay roll is fixed at the highest point. Again several concave grooves are also made on the upper surface of the clay sheet. A clay fence of about one and half inches or more depending on the size of the model is built along the edge of the clay rim covering the entire perimeter around. Next, a covering mould is prepared by pouring thick liquid plaster in the enclosure taking care to leave the tips of the clay funnel and the rolls. Iron rods are inserted into the wet plaster for reinforcement. After the plaster sets the figure is reversed bringing the back side up for moulding. The clay support and the clay rim are removed. The plaster rim of the front side covering mould is cut smooth and concave notches are carved on it at points three or four inches apart. Soap oil emulsion is applied on the rim to prevent the plaster of the back side covering mould from adhering to the front half. Next, moulding of the back half is done as on the front side. When the covering moulds of both sides are ready, the back side covering mould is removed. The clay sheet over the plaster copy is pulled out and the clay rolls are also removed; the holes made by them on the covering mould are trimmed and perfected. Key notches are carved on the rim of the clay sheet of the front half. The inside of the covering mould is given a coating of French polish followed by oil. It is then replaced carefully over the plaster positive, bound and the outside seam between the two covering moulds is sealed properly. In the mean time gelatine is made ready for pouring. It is carefully poured into the vacant space earlier occupied by the clay sheet. As the fluid gelatine begins to run out through the air vents, it is stopped by plugging the holes with clay and is filled up to the top of the pouring cup. Some extra gelatine is kept ready to feed again when the mass begins to settle. Afterwards the mould is checked at intervals and if there is any leakage through the air vents, it is stopped again with clay. The gelatine mould is left to set and cool overnight. After that the same process is repeated on the front side. The front side covering mould is next removed and the gelatine mould of the front and back sides are separated by slicing them apart with a sharp blade at the seam of the both halves. French chalk is dusted on the external surface of the gelatine mould and the internal surface of the plaster mould and the gelatine mould is pressed into the covering mould. The same treatment is done for the back side. Next, the inside of the gelatine mould is painted with a hardening solution made of alum and water, and the mould is reassembled, bound securely and made ready for preparing the wax replica.

The inside of the gelatine mould is checked for the entrapped air while applying hot melted wax. Air block is prevented by cutting a passage through the gelatine and covering mould. Ensuring the release of air is necessary to obtain a perfect replica from a gelatine mould. After that hot melted wax is applied inside the gelatine mould as was done in the piece mould and a wax replica is made for *cire perdue* casting.

The *rubber mould* has come into use only recently.[13] A rubber mould is more pliable, elastic, durable and can be used to make moulds from soft as well as hard objects. Its durability helps to prepare a larger number of wax replicas for eventual casting in metal. The technique of preparing a flexible rubber mould is much simple compared to that of a gelatine or plaster piece mould. Being an industrial product, the compound is available in various forms ready for use. But, the cost of preparing a rubber mould is higher compared to that of a gelatine mould. Hence the cost is a determining factor in the choice of gelatine or rubber for a flexible mould.

A rubber compound for flexible mould consists of: latex rubber, stablizer (ammonia, soap or casein) used for keeping the rubber in a colloidal stage, preservative (ammonia or phenols) to prevent the decomposition of latex, galling or setting agents (magnesium sulphate or ammonium chloride), fillers (earth clay, China clay, whitcing, barium sulphate, talcum, zinc oxide and cotton fibres), vulcanizing agents (flowers of sulphur, zinc oxide), accelerators and antioxidants.

A number of patented rubber moulding compounds are marketed for ready use. The formula of these compounds is a trade secret. One of the known formula is given below in which all the ingredients are compounded in weight. One hundred parts of rubber, as latex concentrate, two parts of sulphur, five to fourteen parts of zinc oxide, ten to fourteen parts of filler, three parts of colour, three-fourths to one part of accelerator, (PPD),* forty four parts of 5% ammonia solution, one part of antioxidant and five parts of stablizer (casein sol. 10%). Further eighteen parts of a solution consisting of 10% ammonium chloride, 10% strong ammonia solution and 80% water is added to the mixture.[16]

All the ingredients of this compound should be mixed in enamelled or glass vessels and it is advisable to avoid copper or brass vessels. The liquid components are mixed first and the powdered ones are then added in small quantities and thoroughly mixed together.

There are a number of techniques for preparing rubber moulds. The choice of a particular technique depends on the nature of the object to be moulded. One of the common techniques is described. This technique consists of applying a thin coat of rubber compound without filler over the plaster copy followed by a thick coat added with filler. The whole is covered over with a plaster covering mould. Usually moulding is done in two halves. However, it depends on the size and nature of the object to be moulded. The plaster copy is treated and arranged in the same manner as described earlier. The first coat is thin and the compound is sprayed or painted over the area to be moulded and allowed to dry. Usually it takes about fifteen to forty-five minutes for a layer to dry. Three or four such layers are given and each is allowed to dry before the next one is applied. To ensure an even and smooth result the medium is applied starting from high areas and worked down towards the bottom. While applying the first layer, special care is taken to make it smooth and ree from air bubble. This is necessary to provide an accurate and smooth inner surface for the mould. The thicker coat is applied over the thin coat with a spatula to bring about a thickness of one-fourth of an inch. But, the precise thickness depends upon the size of the object. After the thick coat sets hard, the back half is turned upward and its rubber mould is prepared. When the entire rubber moulding s over, it is left to cure for forty eight hours in a warm atmosphere. After curing a coat of French polish or varnish or a weak solution of hydrochloric acid (25%) and water is applied over the outer hard surface of the rubber mould in order to retard the action of ammonia on the rubber when it comes in contact with plaster of Paris of the covering moulds. Then arranging fencing walls of clay to divide the rubber mould into front and back halves, covering moulds of both the halves are made as described earlier. When the plaster covering moulds set hard, they are removed. The rubber mould is cut with a sharp blade at the seam and fitted into their respective covering moulds. Then the inside of the rubber mould is cleaned and a coating of French polish or an emulsion prepared by mixing ten parts castor oil and one part alcohol is applied. The rubber mould is now ready for making the wax replica.

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*Piperidinium pentamethylenedithiocarbamate (P.P.D. Trade name United Kingdom.)

The process of making a rubber mould is slightly different from that of a gelatine mould. A rubber mould is prepared directly over the plaster copy, whereas a gelatine mould is produced indirectly by pouring gelatine in the cavity left by the clay cover in between the plaster copy and the covering moulds, the clay cover being removed in the process.

A number of layers of hot melted wax is painted inside the mould until it gets the thickness equal to the metal cast to be made. In between the application of each layer, cold water is applied to harden the wax layer. After the final application the wax is left to harden. It is then released from the mould and sprues, vents, runners, drains and pouring cup are fixed according to the flow cast system for casting.

The wax replica with all the other attachments is weighed and the amount of metal required for casting is computed on the basis of the specific gravity of wax. Comparative specific gravity of some of the metals and wax is given below.*

Approximate specific gravity of wax......1.

Specific gravity of brass (8.46), bronze (8.85), copper (8.94), silver (10.53), gold (19.36), iron (7.86), aluminium (2.7), tin (7.3), zinc (7.10).

B. *Moulding*

(a) Different combinations of the following basic materials are generally used as *Moulding medium*: Grog, plaster of Paris, hydrocol (a hard setting plaster which can withstand high temperature up to 1000°F), cowdung, horsedung, silex (flint), sand, fireclay, vermiculite (altered mica), mica, soapstone, marble dust, pumice, asbestos, talc and graphite. Some known combinations used in certain countries are given below.

In Italy[17] the following combination is used. *First coat*: three parts of grog and one part of plaster of Paris. *Second coat*: one part of grog, one part of plaster of Paris and one part of luto. This compound is used for the core also.

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*Compiled from several sources.

In France[18] the following combination is used. *First coat*: sand and cowdung. *Second coat*: sand and horsedung. *Third coat*: plaster of Paris and silica. After the second coat the mould is reinforced with iron rods and wire and then the third coat is applied. Information about the core mixture is not available.

In England[19] the following combination is used. *First coat*: Plaster of Paris and grog. *Second coat*: luto mixture made up of luto, plaster of Paris and sand. *Third coat*: same mixture as used for the second coat. For the core a composition of grog and plaster of Paris is used.[20]

In the United States* the following combination is used. *First coat*: two parts of hydrocol, three parts of plaster of Paris, three parts of sand, three parts of asbestos and two parts of talc. *Second coat*: half part of hydrocol, two and half parts of plaster of Paris, one part of asbestos, one part of sand, three parts of luto and half part of vermiculite. For core a combination of two parts of hydrocol and three parts of plaster of Paris is used. The dry compounds are measured and kept ready for use.

In Mexico[21] the following combination is used: two parts of soft brick dust and one part of plaster of Paris. The wax model is placed within a fenced enclosure (flask) and the compound is poured in. The same mixture is used for the core.

(b) As a preparatory to moulding the wax model has to be treated and one such treatment prevalent in U.S.A. is described.

First the wax model is wetted to remove the slickness of wax for proper adherence of the first coat of the mould. This is done by applying a mixture of green soap (liquid soap) and hydrogen peroxide or alcohol in equal parts over the wax model.

Before moulding the wax model is firmly fixed over a smooth board by applying some wet investment around the base of the model and allowed it to set hard. Sometimes the model is hung with the tip of the drain just touching the surface of the board. These two modes are used according to the shape of the model to be moulded.

Moulding is done in two processes: hand building and pouring, depending upon convenience and suitability. Sometimes both the processes are combined in making the mould.

The core is formed inside the wax model either at the beginning or at the end of moulding, depending upon convenience. The compound for the core is mixed in water and poured into the interior of the wax model. Sometimes a long wax rod is fixed inside to serve as core vent for the release of gas that forms inside the core, while casting.

For the *hand building process* the dry compound of the *first coat* is mixed in water and applied with a brush or splashing. Care is taken to avoid air bubbles and to infiltrate the investment into the intricate parts. Three or four layers of this coat are given and each layer is allowed to dry completely before the next one is applied. Special care is taken to keep the pouring cup and covering of the tip of the vents free of the investment.

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*Partly based on the study done by the author at the University of Oregon, U.S.A.

The *second coat* composition is mixed with water to a dough-like consistency and carefully patted over the first coat to a thickness of one and half to two inches depending upon the size of the model. Reinforcement is done with iron bands or wire and the mould is left to set hard. When necessary a third coat is applied in a similar manner.

When the required thickness of the mould needed to be made up quicker the moulded surface is enclosed within a fence after the first coat and the wet investment is poured as in the pouring process.

For the *pouring process* a fence little higher than the pouring cup is built around the wax model to enclose it completely. It may be of wood or metal or tar paper and a minimum space of two inches is kept between the model and the inner wall of the fence. The fencing wall is firmly fixed to the ground by applying wet moulding medium around it. It also helps to prevent the seeping out of the wet investment that will be poured into the enclosure.

After placing the wax model within the fence, the different ingredients of the moulding medium are mixed in water and poured in between the wall and the model. This investment fills up to the brim of the pouring cup, leaving out the tip of the vents and the inner cavity of the pouring cup. A slight vibration is made on the surface of the board by tapping, to remove the air bubbles present inside the wet compound. Chicken wire or expanded metal cut and shaped according to the inner shape of the mould area is carefully pushed into the liquid investment to serve as reinforcement. The mould is allowed to set hard.

Usually in the indirect process the work of preparing the wax replica from a plaster copy, moulding, burn out (dewaxing and baking) and casting etc. are done by expert foundry men and not by sculptors. This requires a separate establishment and technical assistance which cannot be afforded by individual sculptors. Besides, the whole work involves technical and manual effort in which a sculptor generally does not wish to waste his time. He simply hands over the plaster copy to the founder after affixing his signature. Some sculptors may have a small foundry of their own for doing small castings. But big commissions are always done by commercial foundries.

C. *Casting*

(a) The foundry establishment consists of: kiln (also called burn out kiln), melting furnace, electric blower, graphite or silicon carbide crucibles of different sizes, foundry tools such as clip tongs, lifting tongs, shanks, skimmer, sledge hammer and devesting tools, safety equipments like face shield, gloves, leggings and leather apron, flux, firebricks, sand or earth filled pits, thermo-couples and gas cylinders.

The basic set up of the kiln used for dewaxing and baking is the same in European countries, United States, Mexico and Chile.[22] The foundries in Italy, France, Spain and England use wood and coke for fuel. In Sweden gas also is used.

In Norway coke, oil and thermostatically controlled electric furnace are also used for this purpose.[23] In the United States, gas, coke, oil and electricity are used depending upon the cheapness of the fuel in a particular place. Oil-fired furnace is used in Mexico and charcoal is used as fuel in Chile.[24] Since the techniques used for burn out and casting do not differ except for the fuel, those adopted in a small foundry using gas as fuel is described.

The kiln is so designed that the walls of the chamber can be dismantled and built according to one's convenience. The perforated floor is built a foot or two above the ground and the gas burners are arranged below it. This arrangement enables the heat from the burners to circulate inside the kiln chamber during the operation. One or two channels lie breadthwise to acquit the melted wax, coming from the moulds into vessels containing cold water kept outside at the tips of the channels.

(b) For the burn out process, the moulds are arranged inside the kiln mounted on two or three bricks leaving some space below the drains. The drains of the moulds face the channels on the floor. After arranging the moulds, the brick walls around the kiln are raised a foot higher than the tallest mould. The thermo-couples are fitted at a convenient point to record the temperature. The top is closed with hemispherical lid having a chimney for the fumes and vapour to escape.

After lighting the burners, heating is started with a low flame and the temperature is gradually increased at the rate of 200°F. per hour. Temperature is allowed to go up to 1000°F. When the wax inside the moulds will be completely drained and burnt off. The moulds also will be devoid of moisture. The temperature is maintained constant at 1000°F. for an hour or two and then it is brought down slowly to 700°F. The burners are put off and the kiln is allowed to cool down. Usually it takes thirty to thirty six hours for a normal burn out. When cooled, the moulds are taken out of the kiln and their bottom drains are sealed with fire clay. The pouring cups and vents of the moulds are plugged with cotton to prevent the dust from getting inside the cavities. The moulds are then arranged inside pits, banked with sand or earth, with their pouring cups facing upward ready for casting.

(c) Usually, standard bronze ingots having a composition of eighty five per cent copper, five per cent tin, five per cent lead and five per cent zinc are used for casting sculptures.[25] However, the Italian craftsmen do use scrap metal of unknown composition.[26]

(d) The process of melting and casting: The furnace is lighted and the metal to be used is pre-heated and broken into small pieces with a sledge hammer. Next, a suitable crucible is kept at the centre of the furnace over a low brick platform and part of the metal is loaded inside it with the help of clip tongs. The furnace is closed with the lid and the flame inside is increased and the blower is switched on for blasting. Melting is watched through the peep hole provided on the lid and as the metal melts and sinks down, some more metal is loaded into the crucible with the help of clip tongs. Thus the needed quantity of metal is heated to 100°F. above its melting point to compensate for the temperature loss which is bound to occur between the unloading of the crucible from the furnace and the actual pouring. By experience the founder is able to determine the correct melting stage of the metal or it is checked with an immersion pyrometer. When the metal is ready for pouring a pinch of borax or some charcoal bits or any other commercial preparation of flux is introduced over the melted metal to clean it and to bring the dross to the top. However, contemporary sculptors who cast their own sculptures with commercially made standard bronze ingots seldom use any form of flux.

When the moulds are ready for pouring, the cotton plugged inside the pouring cups and the vents are removed. The lid of the furnace is removed and the crucible is taken out with the help of the lifting tongs and placed over a layer of fireclay bricks. The floating dross on top of the hot liquefied metal is skimmed off with the skimmer and the crucible transferred to the centre of the shank, which is kept ready for lifting it for pouring. Two persons now hold the opposite ends of the shank and lift the crucible and bring it near the pouring cup of the mould to be filled. Another person holds the crucible with the bent side of the skimmer at the edge opposite to the pouring lip of the crucible. When everything is set under the direction of the master founder they tilt the crucible and pour the metal into the cavity of the mould through the pouring cup. The metal gushes through the down sprues and reaches the bottom of the mould and slowly starts rising up and enters the cavity through the runners of the mould, fills the entire cavity and touches the top of the pouring cup and the vents. At this point pouring is stopped and the metal is watched, if it sinks down fresh metal is fed until the mould is filled to the brim. After all the moulds are filled they are left to cool. If any melted metal is left in the crucible it is poured into some clay containers and the crucible is reloaded into the furnace to prevent sudden cooling.

(e) When the mould is cooled the outer surface and the inner core are raked off with the help of a cold chisel and hammer. Special curved tools are used to remove the investment from the intricate areas. Further, cleaning is done with wire brush to remove the investment that might stick inside the blow holes and small pores.

The investment that is removed from the moulds is carefully stored for future use. It is also known as *luto*.

D. *Finishing*

Various techniques are adopted to finish a cast, the choice which depends upon the effect desired by the sculptor. The finishing is done as follows:

(a) *Pruning* is done with hacksaw, cold chisels and hammer. The sprue, vent and runner rods are cut off with hacksaw just a little above their attached point on the cast and the left off portions are removed with chiselling.

(b) *Pickling* is done to remove dirt and fire skin. The cast is immersed in a solution consisting of five parts of water and one part of nitric acid for some time and then it is removed and dipped in an alkaline solution to neutralise the acidity. The cast is further cleaned in cold running water.

(c) The holes left by the core pins and air bubbles are filled by *tapping* cold metal, cut from the sprue or vent rods of the cast which will be of the same alloy and colour. The tapping is done by tap and die process or deftly inserting the metal with a hammer. Sometimes, such repairs are done by welding.

(d) *Filing and grinding* are done using varieties of hand files and rotary files attached to the chuck of a flexible shaft grinder or angle grinder.

(e) *Sanding* is done with different grades of emery papers or by different grades of emery and aluminium oxide discs attached to the rubber pad of a flexible shaft or disc grinder or emery wheels fixed to the spindle of a polishing and buffing machine. This removes the scratches caused by filing and grinding.

(f) *Chasing and matting* are done with different types of tools such as liners, planishers, doming tools, matting tools, punches and varieties of hammers.

(g) *Polishing and buffing* are done using polishing compounds such as tripoli, rouge, pumice, crocus cloth. These compounds are fed on to the revolving surface of a polishing disc mounted on the chuck of a flexible shaft grinder or the spindle or a polishing or buffing machine. These discs consist of bristle, walrus, felt, cotton flannel and goblets etc. Tripoli and pumice are fast cutting abrasives which are used to remove emery marks and fine scratches. They bring about a smooth but dull appearance to the surface. Rouge brings high colour and lustre by burnishing the metal surface. Crocus cloth too brings about the same lustre when used by hand.

(h) The cast is *cleaned* in hot soap water added with a few drops of ammonia and brushed with wire brush to wash away the particles of rouge and tripoli or pumic that might stick to the crevices and corners. After cleaning, the surface is wiped with chamois skin and polishing cloth.

(i) *Patination* is used for creating certain surface effects on copper and copper based-alloys. The technique of applying patina is a highly specialized art almost kept as a trade secret by specialists. Some of the known techniques are the exposing to natural environment (traditional) and chemical treatment.[27]

Chemical treatment consists of burial process, fume process, cold process, hot process and dip process.

For the *burial process* the cast is kept buried in saw dust saturated with chemicals. The chemicals work over the surface and creates patina.

In the *fume process* the cast is kept inside a plastic or glass container along with an open dish, containing special chemicals. The fumes of the chemicals act on the surface and create patina. Liver of sulphur helps to bring about a black patina and hydrochloric acid and water a green patina.

In the *cold process* the chemicals are brushed or sprayed over the surface.

In the *hot process* the cast is preheated with a blow torch and the chemical mixture is sprayed or brushed.

In the *dip process* the cast is kept in a chemical mixture for some time. Different chemical formulas are used to obtain different colour effects. Some of the known formulas are given below:

For producing green colour effect a mixture of thirty seven parts of sodium chloride, thirty seven parts of ammonium chloride, seventy five parts of ammonia water and five hundred parts of strong wine is used.

For producing an antique green effect a compound containing one part of cupric nitrate, one part of ammonium chloride, one part of calcium chloride and four hundred parts of water is used.

For producing a blue effect a compound consisting of forty parts of ammonium chloride, one hundred and twenty parts of ammonium carbonate, and hundred parts of water is employed.

The formula used for the dip process is suitable for the cold and the hot processes also.

III. CONTEMPORARY TECHNIQUES

New Materials and techniques developed by contemporary advances in technology have been successfully adapted by sculptors of today for their works. The developments mostly relate to materials and methods involved in modelling, carving, moulding and eventual casting in metal.

Apart from the materials for preparing an original, already described, the contemporary sculptors now mostly use *micro-crystalline wax* derived from petroleum which is found to be a better substitute to beeswax compound as a modelling medium. It does not need any additive except a colour to give a dark shade for clarity. This wax is available in a purified form and is marketed in forty different grades having melting point ranging from 145 to 300°F. which enables a sculptor to choose the grade that suits his specific need. This wax permits modelling and carving techniques simultaneously with or without the use of heat and is also used for preparing wax replica in the indirect process already described.

Again, nowadays a sculptor has not to depend on a malleable compound for modelling an original. Foam plastic, a by-product of plastic, has largely been in use for packing and insulation. The sculptor has also discovered its potentiality since it can easily be lent shape by carving, sawing, rasping or joining pieces together by epoxy adhesive or pins. Light and rigid foam plastic is also used as an armature support for modelling large figures for eventual casting.

The advantages of a flexible mould have already been described. Nowadays a number of new materials like Polyvinyl rubber, Polyurethane rubber, Silicone rubber and Agar have come into use for this purpose.

Polyvinyl rubber, a product of polyvinyl chloride, is used just like gelatine for flexible moulds.[28] But in comparison to gelatine it is strong, durable and lasting. Further it can be re-used several times. Its melting point ranges between 350° and 360°F. For flexible mould it is cut into small pieces and melted in a double boiler having castor oil in between the two walls or in an electric oven.

Polyurethane rubber consists of two liquid components. The two are mixed together and applied immediately since the mixture has a pot life for half an hour only; curing takes place within sixteen hours in a warm atmosphere.[29]

Silicone rubber: Silicones are extremely stable organic derivatives of silicon (silicium), a non-metallic element obtained from silica (silocon dioxide) occurring in nature as sand or quartz. A number of products have been developed from silicones. Among them, silicone rubber is produced by mixing together liquid silicone polymer and a special type of catalyst. Silicone rubber has been found to be a versatile medium for flexible mould. It is used for making two types of flexible moulds; the skin mould and the cast mould.[30]

Preparation of a *skin mould*: Thin mixture of the rubber compound is brushed over the plaster copy to form a film all over. The *first coat* consists of two layers. Each layer is allowed to dry completely before the next is applied. An infrared heat lamp or an electric room heater is used to accelerate the drying time. The *second coat* is built up over the first coat by applying cheese cloth or loosely woven dacron or fibre glass cloth saturated with the rubber compound. The total thickness is built up to 1/8th inch. The mould is left to cure for twenty four hours in a warm atmosphere. Over the skin mould a two piece covering mould is fashioned as described earlier. Information provided in the relevant literature does not say that the skin mould underneath the covering mould needs to be sliced at the seam of the two halves of the covering mould or skinned out from the plaster copy and fitted into the covering mould; it has to be inferred.

Preparation of *cast mould*: The plaster copy is mounted over a sheet af cellulose acetate and a box like enclosure is built around with thick plywood sheets, leaving sufficient space all around equal to the thickness of the cast mould to be prepared. The inner surface of the enclosure is brushed with 5% petroleum jelly and methylene chloride emulsion to prevent the rubber compound from adhering to the wood surface.

To determine the amount of silicone rubber required to make a mould the cavity inside the enclosure is filled with sand and its weight is determined. This will give the approximate weight of the silicone rubber compound required for preparing the mould. When everything is set the moulding compound is filled in the cavity between the model and the enclosure and is allowed to cure. When ready the box and the acetate sheet are taken apart. The silicone mould is incised vertically along one side which extends partly to the bottom. When the cut ends are flexed the plaster copy is easily released. The mould is reset inside the box to prevent distortion while preparing the wax replica.

Sometimes a silicone rubber piece mould is made by dividing the plaster copy as described in plaster piece mould process. The enclosure for each section is prepared with modelling clay or wax sheet. Petroleum jelly emulsion is used as separator to prevent adhesion of each section while moulding. The complete piece mould is kept enclosed inside a wooden box as described earlier.

The process of making a silicone rubber mould is slightly different from that of a latex rubber mould. In this there is no need to apply a separator over the plaster copy before moulding.

For preparing a wax replica melted wax is applied inside the rubber mould equal to the thickness of the cast required in metal.

The advantages of a silicone rubber mould are: (1) No separator to be applied over the plaster copy before moulding. (2) The mould can be cured in five minutes at a temperature of 300°F. (3) As the shrinkage is very little it is possible to get an exact reproduction of the original model. (4) When precoated with silicone or wax preparations the mould can be used to make hundreds of wax replicas for *cire perdue* casting. (5) Old moulds can be retrieved for reuse. For this they are heated for an hour at 550°F. to drive away the contaminants; then are washed in a chlorinated solvent to remove any other foreign matter present. After washing they are ground in a meat grinder. The reclaimed material is mixed with freshly catalyzed silicone rubber.

Agar is a vegetable gelatine processed from marine algae found largely in Indian and Pacific Oceans. The technique of using it for flexible mould was developed during the first world war. This material is specially suitable for preparing moulds from living flesh as its hardening temperature is only, slightly above human body temperature. The American Museum of Natural History recommends its use for preparing moulds for wax replicas. The formula recommended is as follows: agar six ounces, water one quart, glycerine three pounds and carbolic acid few drops.

The method of preparing and using it is described below: Fully soaked agar is boiled in a double boiler and glycerine is added. The boiling is continued until the water evaporates. Next, carbolic acid is added and the mixture is allowed to cool. When cool, it will have a rubber-like consistency. Before use, it is cut into small pieces and melted. When liquefied in a moderately warm condition it is poured over the plaster copy.[31]

While using this flexible media the plaster copy is treated in the same way as described earlier for flexible moulds.

There have been advances again in respect of the media and method of moulding for eventual casting in metal. Some of them are: ceramic shell process; CO_2 silicate process; self-setting sand process; and investment casting.

The ceramic shell moulding process[32] was discovered a few years ago and is now being largely used in preference to the usual plaster mould method employed for *cire perdue* casting. The ceramic shell mould process has certain distinct advantages especially for small castings. This mould is strong, light, thin and is able to withstand high temperature. Very fine details can be reproduced in this method. Time required for moulding is again very short and burn out takes very little time. Devesting is easy, except in undercut areas. It requires a simplified sprue system with only the pouring cup and one sprue.

The basic materials for ceramic shell moulding are: Three hundred and thirty five mesh of silica flour, twenty mesh of grog and sodium silicate solution binder.

Before moulding the wax model is cleaned with alcohol or with an emulsion prepared with hydrogen peroxide and green soap.

For moulding, a viscous solution is prepared with silica flour and sodium silicate solution. The wax model is dipped into the slurry several times, or the slurry is sprayed with a spray gun. Along with the dipping or spraying of the slurry, grog is sprinkled over each layer. Each layer is allowed to dry before the next one is applied. If available CO_2 (carbon dioxide gas) can be used to shorten the time of the drying. Steel wire or fibre glass netting is employed for reinforcement.

For dewaxing two methods are followed: (i) chemical treatment, (ii) heating the mould.

For chemical treatment, the mould is kept inside a net basket and immersed in a trichlorethylene vapour bath.[33] The vapour permeates the porous shell and dissolves the wax. Sometimes trichlorethylene solution is also used to dissolve the wax. A mould weighing seven to eight kilos takes about thirty to forty minutes for dewaxing.

For the heating process the burn out kiln is preheated to 2000°F. and brought down to 1000°F. The mould is then loaded into the kiln and the temperature is maintained at 1000°F.; it takes about five minutes for the wax to drain off.

For baking the mould for casting after dewaxing the temperature of the kiln is increased to 2000°F. The mould gets ready for pouring within fifteen to twenty minutes depending upon the size of the mould. If the casting is to be done later the mould is stored off. The mould is reheated to 400°F. before use.[34]

CO_2 silicate process: In this process the chemical reaction taking place between sodium silicate and carbondioxide plays a major role. Though it is primarily employed in industry its use is extended for *cire perdue* casting also. The ingredients for the moulding media in this method are as follows: washed river sand, sea coal, gilsonite, iron oxide, sodium silicate, graphite, silica, flint, molasses, sugar, plaster, vermiculite, fireclay, and CO_2 gas. Of these ingredients different compositions have been developed as the moulding media. One of these is being described here.

Moulding is done in two stages such as: (i) applying the moulding medium over the wax model with a brush and (ii) packing. Before moulding the wax model is cleaned with a cleaning agent.

In the first stage a viscous slurry is prepared by mixing thirty five parts of graphite, fifty parts of silica and fifteen parts silicate in water. The slurry is applied with a brush all over the wax model taking care to leave the mouth of the pouring cup and the tips of the vents. It is allowed to dry completely. Next inside a core box it is packed with a composition consisting of the following: one hundred parts of washed river sand, fifty parts of gilsonite (sea coal), four parts of molasses and four parts of sodium silicate.[35] Sand, gilsonite and molasses are mixed together first and sodium silicate is mixed just before packing. For packing a layer of the composition is spread on a flat board, the core box and the partly moulded model is carefully laid over it so that the rim of the pouring cup and the tips of the vents touch one of the walls of the box. Next packing is done with the same composition all around carefully. After this carbondioxide gas is introduced into the composition through a cup or a needle. The mould sets hard quickly. It is released from the box and is strengthened by binding with wire or angle iron.

A regular burn out kiln is not used for burn out instead the work is done in a core oven. Burn out takes about four hours at 500°F.[36] By then the mould gets ready for casting which is done in the usual way.

Self-setting sand process is a method developed by industry and adapted by sculptors for their use. The ingredients used by weight for moulding are: one hundred parts of 200 mesh fine silica sand, two parts of resin binder, phosphoric acid catalyst, twenty parts of the weight of the resin, one part of clay, and one part of red iron oxide.

For moulding the compound is mixed in a mulling (mixing machine). The dry silica sand is first put into the machine and then the dry additives and resin are added and mixed for two to three minutes depending upon the quantity of the mixture. After that the catalyst is added and mixed again for two to four minutes. The mixture takes about ten minutes to set and twenty four hours for curing.[37]

For direct process of hollow casting wax sheets are applied over a pre-shaped core form prepared from the same moulding compound and finished as required.

Moulding for *cire perdue* casting of a wax model or a replica is done with the above mentioned moulding compound in the same manner as described under hand building and pouring processes in section II of this chapter.

Dewaxing of a mould is done by heating it to 450°F. approximately. No baking is done. Casting is done in the usual process as described earlier.

Investment casting process is used in industry for casting precision machine parts which cannot be forged or machined. This process has very little relevance to the scope of this dissertation and need not be described in detail. The wax replica is made from a wax compound made by blending, beeswax, carnauba wax, ceresin wax, acrawax, paraffin and other resins. The wax compound is injected into a metal mould at 150° to 170°F. and at a pressure of 500 to 1000 psi. After removing the replica from the mould sprue system is attached. Moulding is done in two stages. For the *first coat* a slurry is prepared by mixing 375 mesh of silica flour with water-ethyl silicate solution. The wax replica is dipped in the slurry and kept drying for ten hours. After that the partially moulded wax replica is enclosed within a metal flask and a liquid investment prepared by mixing eighty parts of plaster of Paris and twenty parts of asbestos fibre or thirty parts of plaster of Paris and seventy parts of silex mixed in water is poured in the inter space between the partially moulded wax replica and the flask. Slight vibration is given to remove the air bubbles inside the investment and the mould is allowed to dry for six to eight hours. After that regular dewaxing, burn out, casting and devasting are done.[38]

For casting a foam plastic sculpture two methods are used. It is either by moulding in regular plaster investment or in a sand mould. In both these techniques the method of moulding is slightly different from the usual one.

In the plaster investment process after fixing the regular sprue system suited either for the gravitational or flow-cast system the model is moulded in a plaster investment as described earlier. After the mould is dry, the foam sculpture is vapourised using any one of the solvents such as lacquer thinner, turpentine or acetone which leaves a hollow cavity inside the mould.[39] Then the mould is passed through the regular baking and casting processes.

In the second method, the sculpture is packed in moulding sand*, the same sand used for casting machine parts in commercial foundries. For moulding a core box or flask is placed on a flat board and a layer of moulding sand is spread over it. The foam sculpture is carefully embedded in the sand with its sprue system facing upward. Sufficient space is left all around for the thickness of the mould. Moulding sand is packed all around and in the interior areas of the sculpture without injuring the delicate parts. If the height of the sculpture extends beyond the height of the first core box another one is fitted over it. This is done until the enclosure extends a little above the tip of the pouring cup and the vents. After the moulding is done melted metal is poured through the pouring cup. The metal burns off the foam plasticand occupies its place and forms the cast.

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*Known as cavity-less casting.

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A COMPARATIVE ANALYSIS OF TRADITIONAL INDIAN AND CONTEMPORARY WESTERN TECHNIQUES

The Indian tradition in *cire perdue* casting as it exists today may be compared and contrasted with profit with the contemporary developments in *cire perdue* casting in the west. This may lead to certain suggestions for improvements of our traditional techniques within the means and resources available.

One of the noticeable shortcomings of our traditional craftsmen is their exclusive nature, a false sense of superiority of their own techniques, and a tendency to disregard the methods used by craftsmen elsewhere. Such a conservative outlook prevents them from making progress in the technical knowledge of their work. In contrast to this the sculptors and founders in the west keep open mind to study and adopt the best that is available from everywhere and also constantly strive for improving their own techniques. This attitude has helped in the use of new materials and methods in the west for *cire perdue* casting.

In our analysis and comparative assessment, the subject has been divided under four broad heads: A. Modelling, B. Moulding, C. Casting, and D. Finishing. These broad heads have been further subdivided into several sub-headings.

A. *Modelling:* (a) modelling media; (b) modelling tools; and (c) preparation of the wax model for solid and hollow castings by the direct process and for the wax replica in the indirect process. Next comes the weighing of the wax model or replica to ascertain the ratio of different metals used for casting in proportion to the weight of the wax.

B. *Moulding:* (a) new materials used for preparing the moulding compound; (b) preparation of the moulding compound; and (c) method of moulding.

C. *Casting:* (a) foundry establishment for burn out process, casting and devesting; (b) burn out process; (c) alloy for casting; (d) melting process and casting; and (e) devesting the mould.

D. *Finishing:* Tools and techniques of finishing.

A. *Modelling*

(a) A comparison of the basic materials used by the treditional Indian craftsmen of today and the contemporary sculptor of the west show that the Indian craftsman has not brought about any marked change in the choice of the ingredients for his wax compound, whereas the western sculptor has been striving to develop new compounds according to his specific needs and also adopted the new materials that are released by recent technology for his specific use. Hence we find the Indian craftsman still using beeswax as the basic modelling medium whereas the western sculptor has taken to the use of micro-crystalline wax because of its advantages.

(b) The Indian craftsman has a set notion regarding the preparation and use of different tools and equipments for his work. This has prevented him to improve as well as to add to the array of his tools. In contrast to this, the sculptor of the west is less dogmatic regarding the tools. Hence, he develops new tools as occasion demands. For example, he has found the electric soldering rod primarily meant for soldering as a versatile tool for modelling in wax as it eliminates the constant need to heat a tool during the process of working.

(c) Regarding the preparation of a wax model for *cire perdue* casting the Indian craftsman invariably follows the direct process, which permits him to make only one cast at a time. Whereas the sculptor in the west uses both direct and indirect processes according to the nature of the work. Hence, he has developed new techniques for the indirect process. It helps him to execute his original in other media than in wax and still procure a cast in metal by the *cire perdue* process. Using indirect process he can also make a number of copies of his original creation. Besides, he tries to use unconventional media in his attempt to develop new techniques akin to *cire perdue* casting. One such technique is the use of foam plastic in the casting of sculptures in metal.

A comparative study of the sprue system* used by the traditional Indian craftsman and the sculptor of the west show that the former has not done anything to develop it according to his needs.

The Indian craftsman is interested only to provide a simple arrangement to feed the metal into the cavity of the mould during casting. Hence, he has not cared to study the definite relationship needed in fixing the sprue vent, runners and drain in relation to the nature of the casting, the areas to be fed, the metal that is used and to obtain a perfect casting.

Two types of sprue systems are used in *cire perdue* casting based on the methods to be followed in feeding the metal inside the cavity of the mould during casting. They are the gravity and the flow-cast systems. In the former the arrangement of the sprue system is simple. In this the metal flows from the top to the bottom and does not take much time to fill the cavity of the mould. This system is mostly used for simple castings. The flow-cast system is the best way to feed the metal into the cavity of a mould, because there would be less turbulence in the mould during feeding operation. There is less likelihood of breaking small parts inside the cavity, as the metal gradually rises upward rather than coming down with force from the top. The sprue system in this process is based on the scientific understanding of the reaction of the liquefied metal inside a mould during the process of cooling.

The Indian craftsman invariably uses the sprue system suited to gravity casting for both solid and hollow castings. Hence, at times he meets with such defects in his casting like blow holes, fractures, spongy metal surfaces etc. Since he has no correct understanding of its function he has not tried to improve his sprue system. In contrast to this, the sculptor with the founder in the west has been studying the relation of the sprue system to eventual casting in metal. Hence he has been constantly striving to improve the sprue system and has found the flow casting system especially ideal for large figures.

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*Sprue system is the common term used in fixing the sprue, vents, runners, drain and pouring cup etc. for feeding the metal inside the cavity of the mould while casting. However, it has two functions, one is to provide channels for the wax to drain out of the mould during dewaxing and the other is to provide channels for feeding the metal into the cavity of the mould during casting.

As regards the method of ascertaining the amount of metal required for casting in proportion to the weight of the wax model, the Indian craftsman has a rough idea based on his long experience. Hence, his understanding is limited to the metals he usually handles, whereas in the west it has been developed on a scientific basis in relation to the specific gravity of wax and the different metals used in casting.

B. *Moulding*

(a) There are two fundamental types of binding materials used in forming a core and mould over a wax model for *cire perdue* casting. They are the plastic clay and plaster of Paris. For centuries, clay has been the only medium used and plaster of Paris came into use during the Renaissance in the west.

The traditional Indian craftsman uses plastic clay and some organic materials as ingredients for preparing the moulding compounds, which he procures from the neighbourhood without much difficulty. But, he has no understanding of their correct use except that his long experience through centuries has made him an adapt in his work to a certain extent. On the other hand in the west today it has been developed on a scientific understanding of the reaction of each ingredient used in making the compounds. Hence, a number of formulas have been developed suited to different types of metals and alloys.

(b) Usually the Indian craftsman prepares two varieties of clay compounds for moulding which involves much time and energy. The sculptor in the west depends upon many industrial products which can be procured easily and the preparation of their moulding compound does not take much time and energy.

(c) As regards the method of moulding the clay-bound system used by the Indian craftsman is slow and time consuming. Normally a single mould takes a week to get ready for dewaxing. In contrast to this the plaster-bound investment used in the west take only a few hours to prepare a normal size mould.

C. *Casting*

(a) Though there is not much of difference in the basic set up of the foundry establishment for dewaxing, baking, casting and devesting between what is used by the Indian craftsman and the founders of the west, the latter has tried to profit from the modern technological innovations in various types of tools and equipments. The Indian craftsman, due to his conservative outlook, is slow to improve his tools and equipments.

(b) As regards the burn out process, the technique used by the Indian craftsman as well as the western founder is basically the same, except for certain minor processes and the fuel used. The Indian craftsman still relies on cowdung cakes, coke, cocoanut fibre and wood for the fuel. The western sculptor and founder make use of chemicals, gas, oil and electricity. All these depend on the technological advancement.

(c) The Indian craftsman today invariably uses brass for his castings, though he claims to know the technique of making different types of alloys. In contrast to this the western sculptor prefers to use standard bronze for his castings. But he also ventures to cast his sculpture in modern metals such as stainless steel, aluminium and aluminium bronze.

(d) The basic technique used for melting and casting is not much different. But the western founder has tried to take advantage of the contemporary technological advancements in designing his furnace and in the use of fuel for melting the metals.

(e) In this process practically one does not find any difference.

D. *Finishing*

The Indian craftsman invariably depends on his traditional tools for most of his work. Hence his work is slow and strenuous. The western sculptor has adapted the various power-tools to his advantage for saving time and energy and for better finish.

Note: The four tables on the following pages give a comparative assessment of the media and method used in India and in the west at the present day.

TABLE I

Flexible Moulding Media

Indian	*Western*	
Traditional	*Modern*	*Contemporary*
	Gelatine, Agar	Gelatine, Latex rubber, Polyvinyl rubber, Polyurethane rubber, Silicone rubber, Agar.

TABLE II

Fuel

Indian	*Western*	
Traditional	*Modern*	*Contemporary*
Cowdung, Charcoal, Wood, Coke, Cocoanut husk.	Charcoal, Coke, Gas, Oil and Electricity.	Gas, Oil, Electricity.

TABLE III

Modelling and Carving Media

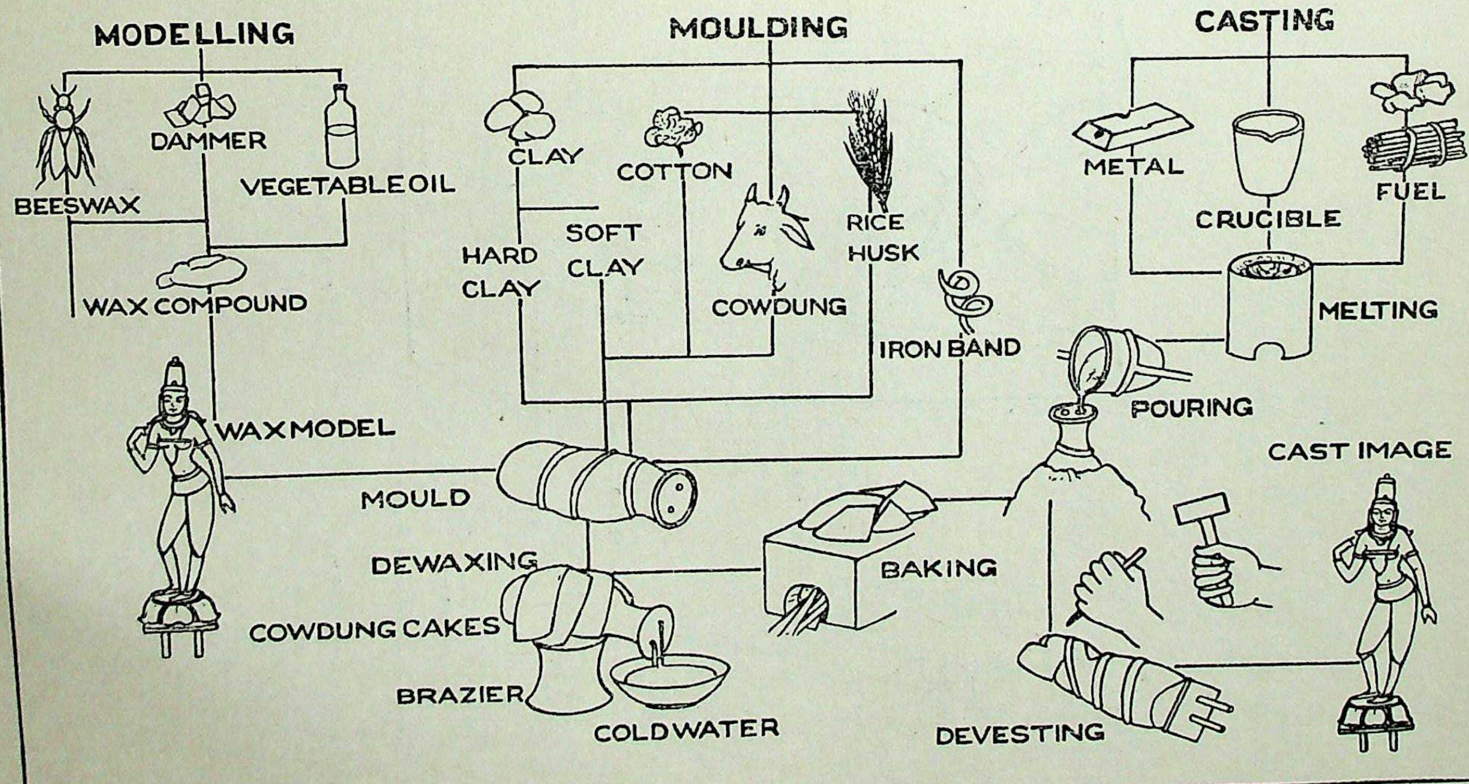
Indian	*Western*	
Traditional	*Modern*	*Contemporary*
1. Beeswax+Rosin+Castor oil or mustard oil or sesame oil or groundnut oil or Mahua oil.	1. Beeswax + Carnauba wax + Paraffin wax + Lead oleate.	1. Microcrystalline wax+Petroleum jelly+Colour pigment.
2. Beeswax and charcoal.	2. Beeswax+Paraffin wax +Rosin.	2. Microcrystalline wax+Mineral oil + Colour pigment.
	3. Beeswax+Rosin+Olive oil+Calcium carbonate.	3. Microcrystalline wax + Colour pigment.
	4. Beeswax+Lead oleate.	4. Foam plastic.
	5. Beeswax+Paraffin wax +Lead oleate + Petroleum jelly + Coco butter+Lanolin.	
	6. Beeswax+Paraffin wax +Lanolin+Lead oleate +Venice turpentine.	
	7. Beeswax + Carnauba wax + Caresin + Holo wax+Paraffin wax.	

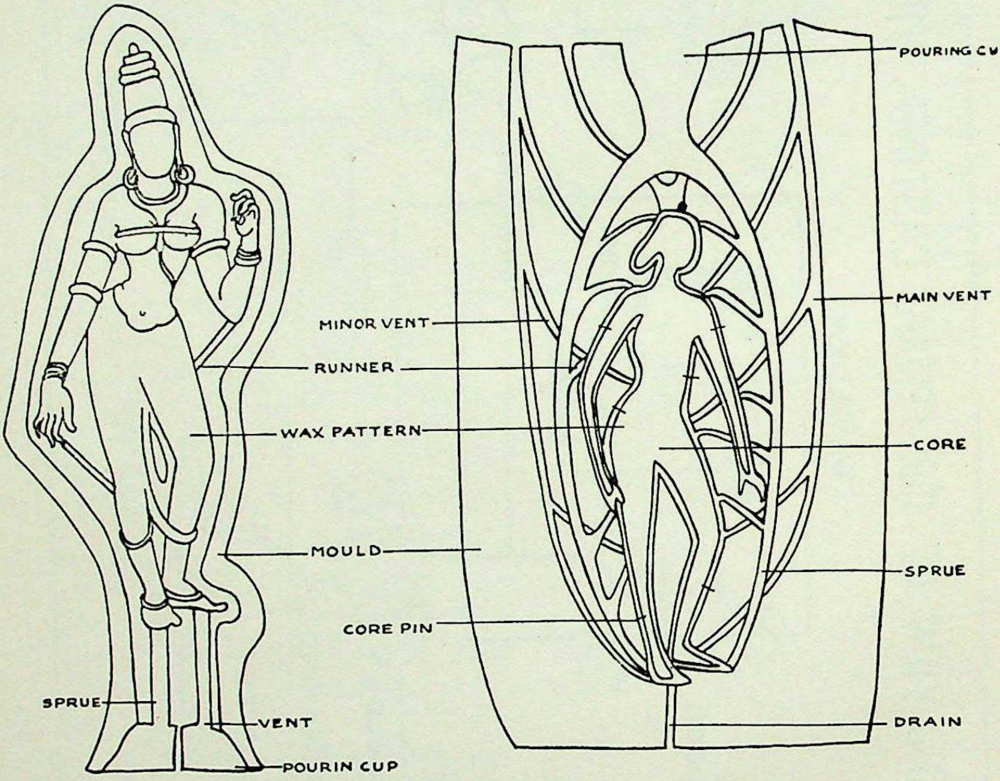
TABLE IV

Moulding Compound

Indian		*Western*		
Traditional	*Modern*	*Cotemporary*		
Clay bond	*Plaster bond*	*Shell moulding*	*CO_2 Process*	*Self setting sand process*
1. Loam + Sand + Cowdung	1. Plaster + Sand + Asbestos + Talc.	1. Grog + Silica + Sodium silicate.	1. Sand + Coal + Gilsonite + Silica + Sodium silicate + Molasses	1. Silica + Resin binder + Sodium Silicate + Phosphoric acid (catalyst) + Clay + Red iron oxide.
2. Soft clay + Burnt clay + Sand + Jute cuttings + Green leaves + Rice husk.	2. Plaster + Sand + Luto + Asbestos.			
	3. Plaster + Burnt clay.			
3. Soft clay + Coarse clay + Jute cuttings + Cotton.	4. Plaster + Burnt clay + Luto.			
	5. Plaster + Sand + Asbestos.			
4. Soft clay + Coarse clay + Jute cuttings + Cowdung.	6. Plaster + Silica.			
5. Soft clay + Coarse clay + Cotton + Rice husk.	7. Plaster + Soft clay + Burnt clay + Luto + White of egg + Gum Arabic.			
6. River clay + Ant-hill clay + Goat-dung.	8. Plaster + Luto + Fireclay + Vermiculite.			
	9. Plaster + Fire-clay + Vermiculite.			
	10. Plaster + Fireclay + Burnt clay + Sand + Asbestos.			
	11. Plaster + Fireclay + Flint.			

DIAGRAMMATIC VIEW OF CIRE-PERDUE CASTING, TRADITIONAL

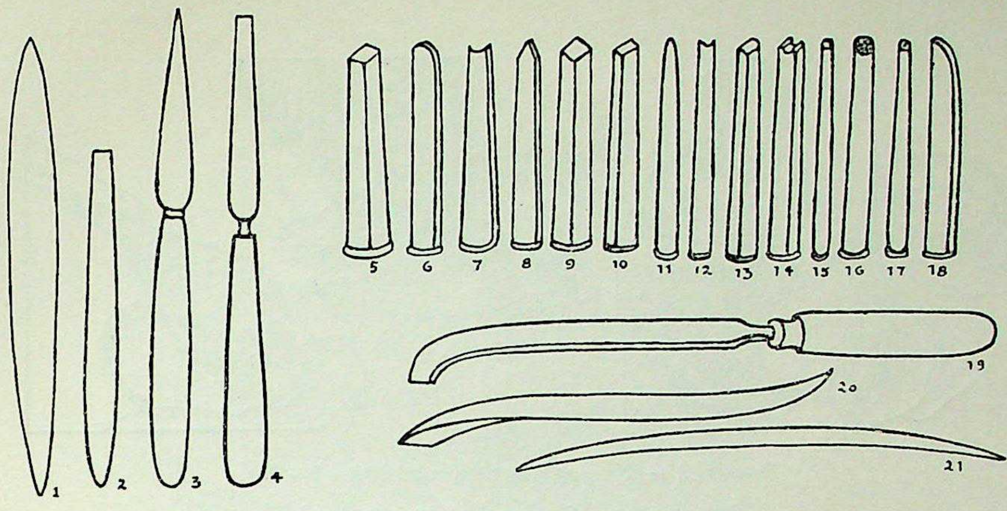

MODELLING
BEESWAX
DAMMER
VEGETABLE OIL
WAX COMPOUND
WAX MODEL
MOULDING
CLAY
HARD CLAY
SOFT CLAY
COTTON
COWDUNG
RICE HUSK
IRON BAND
MOULD
DEWAXING
COWDUNG CAKES
BRAZIER
COLDWATER
BAKING
CASTING
METAL
CRUCIBLE
FUEL
MELTING
POURING
DEVESTING
CAST IMAGE


RUNNER
WAX PATTERN
MOULD
SPRUE
VENT
POURIN CUP
POURING CUP
MINOR VENT
MAIN VENT
CORE
SPRUE
CORE PIN
DRAIN

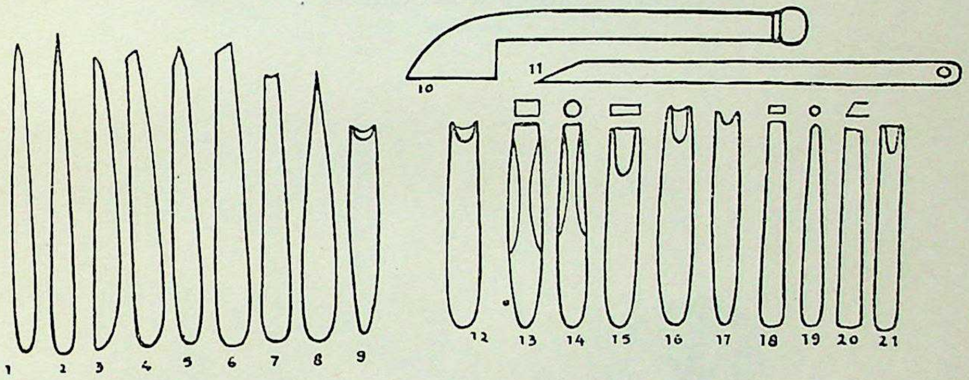
GRAVITY CAST SYSTEM

FLOW CAST SYSTEM

A.



B.



Wax Modelling and Metal Finishing Tools of Craftsmen of Swamimali, Tamil Nadu & Varanasi, U.P.

A. TAMIL NADU

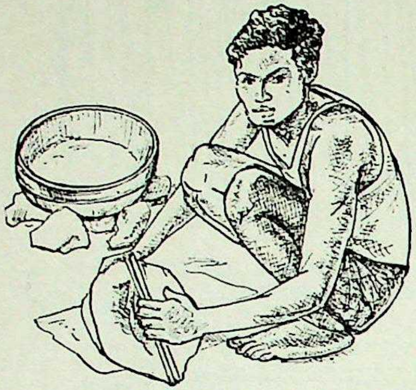
FIGS.

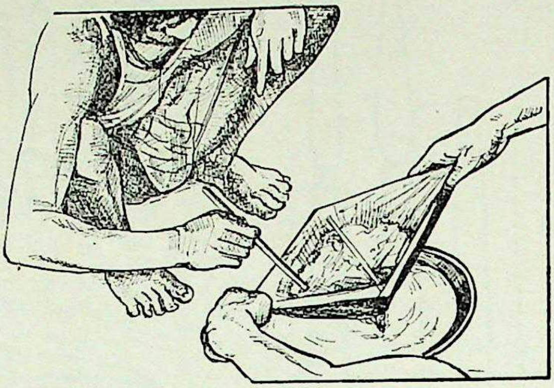
1, 2 — Wooden spatulas
3, 4 — Steel knives
5 — Flat chisel
6 — Convex chisel
7 — Concave chisel
8 — Diamond pointed chisel
9 — Sharp lozenger shaped chisel
10 — Square headed tool
11 — Round headed tool
12 — Curved (light) shaping tool
13 — Curved tool
14 — Bangle tool
15 — Linear
16 — Flower design tool
17 — Eye tool
18 — Circular headed tool for rounding of two corners
19 — Flat scraping chisel
20 — Circular headed scraping chisel
21 — Curved chisel

B. Wax Modelling and Metal Finishing Tools Craftsmen at Varanasi, Uttar Pradesh

FIGS.

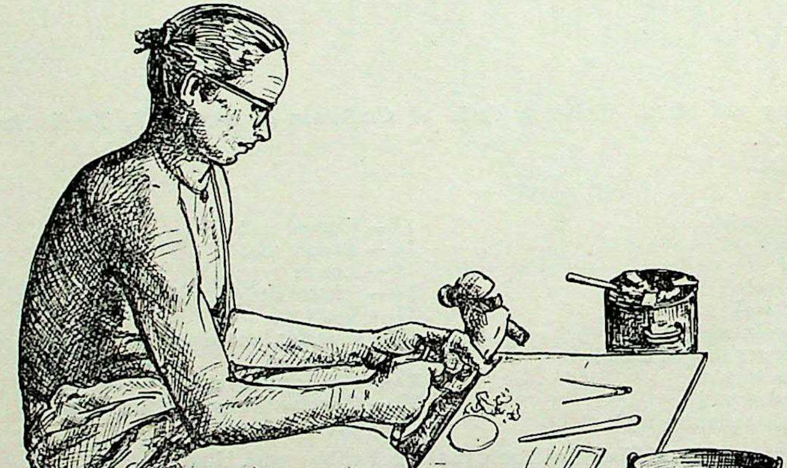
1 to 9 — Modelling tools
10 — Plainer
11 — Steel knife
12 — Concave tool
13 — Square headed tool
14 — Round headed tool
15, 16 — Half-round tools
17 — Linear
18 — Rectangular headed tool
19 — Linear
20 — Angular cutting tool
21 — Curved tool



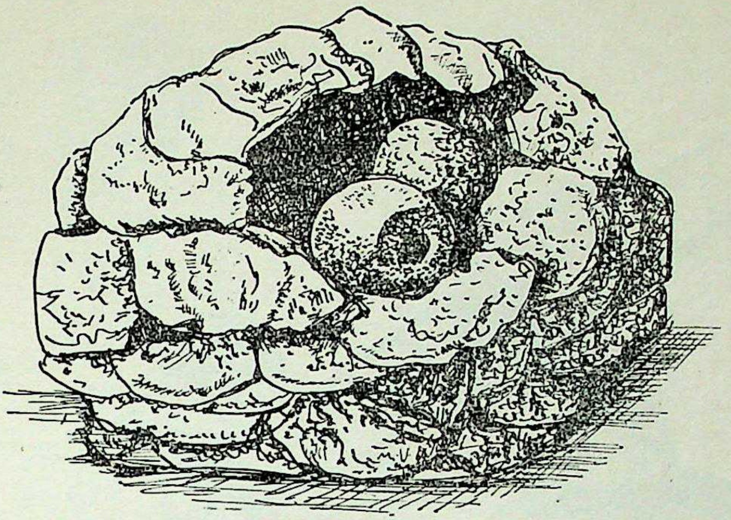


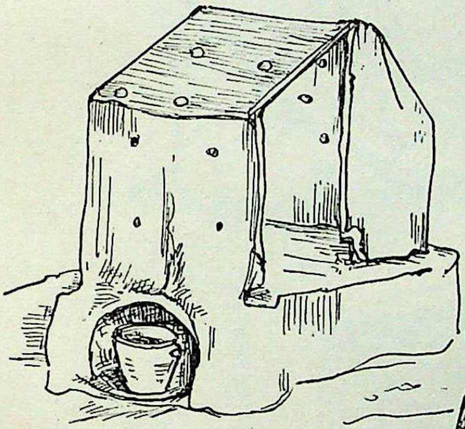
Drawing I — Heating wax compound over a low fire.

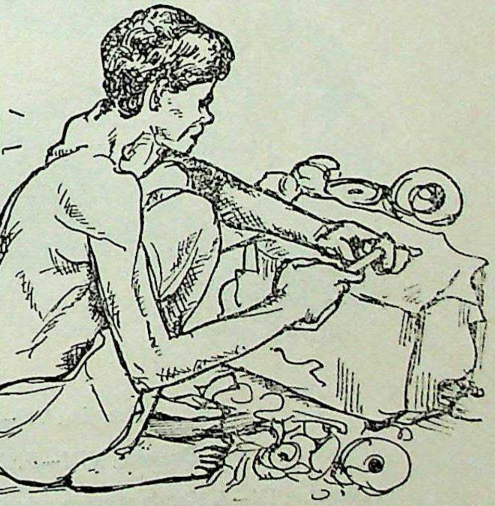
Drawing II — Filtering the wax compound.



Drawing III — Modelling a wax image.



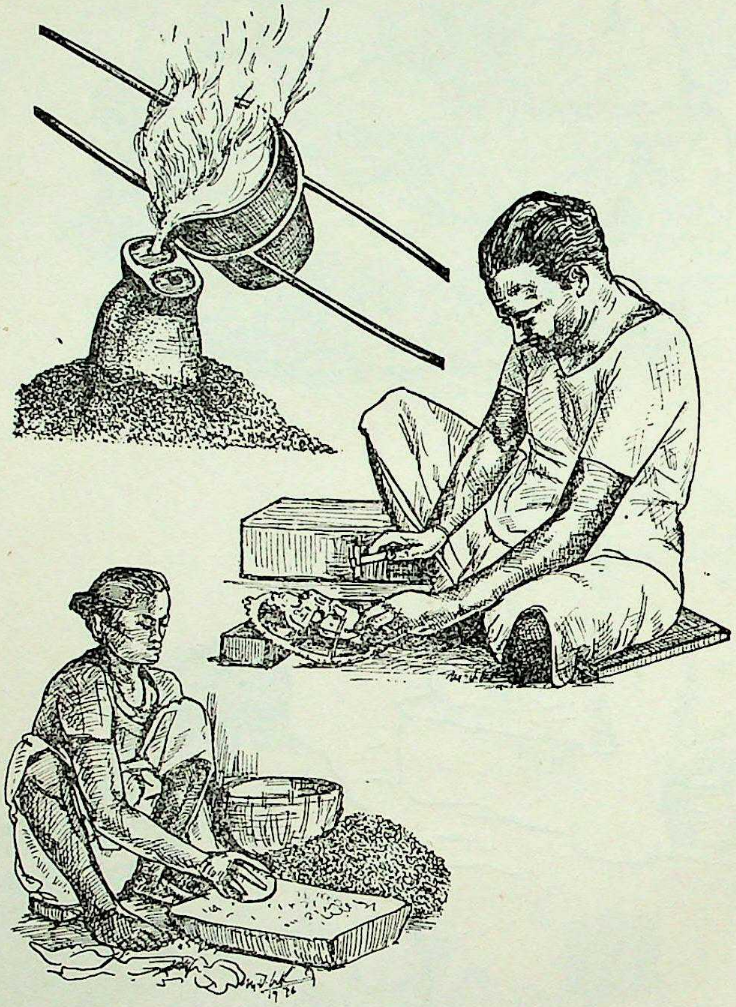




Drawing IV—Baking the mould.

Drawing V—An oven-cum-melting furnace.

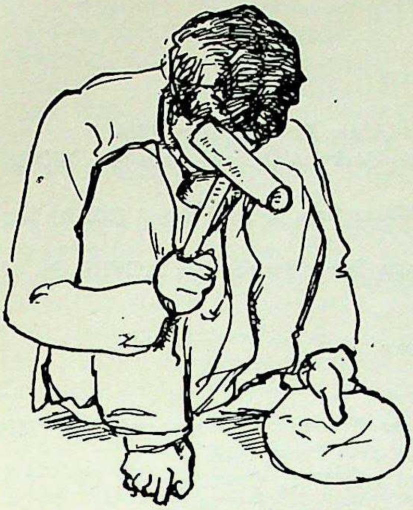
Drawing VI—Braking the scrap metal.

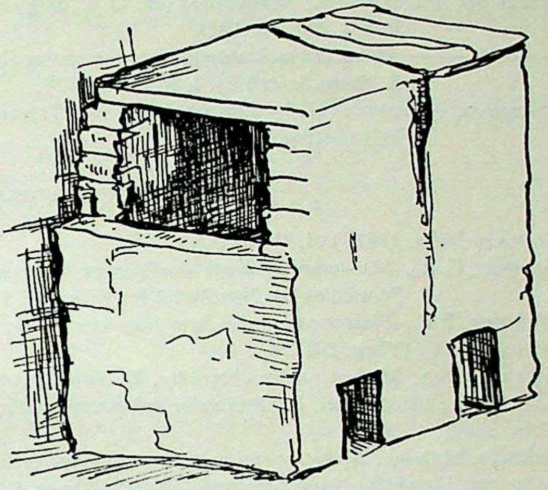


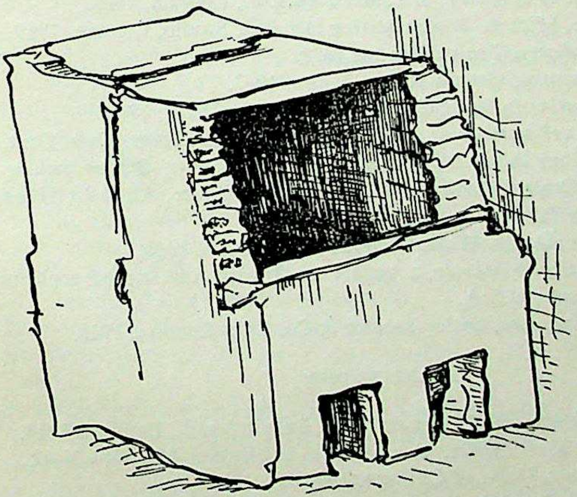
Drawing VII—Casting.

Drawing VIII—Finishing a cast.

Drawing IX—A Kerala woman grinding the moulding compound.







Drawing X—Preparing wax sheets, Nepal.

Drawing XI—Dewaxing and baking oven, Nepal.

Drawing XII—Melting furnace, Nepal.

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GLOSSARY

INDIAN TERMS

Ābanūsa (आबनूस—Hin.)—Ebony wood.

Āgé muhā chaurasiyā (आगे मूवा चौरसिया—Hin.)—Diamond pointed chisel. *Kirtimukham* (Tam.), *Gorū pogarā* (Tel.).

Angulā (अंगुला—Sans.)—A unit of measurement.

Araivaṭṭa aram (अरैवट्ट् अरम्—Tam.)—Half round file. *Ardhagola reti* (Hin.).

Ardhagola reti (अर्धगोल रेती—Hin.)—Half round file. *Araivaṭṭa aram* (Tam.).

Aśtadhātu (अष्टधातु:—Sans.)—An alloy of eight metals.

Badāmā (बदामा—Hin.)—Rectangular headed tool. *Vaṭṭi pogarā* (Tel.), *Taimurati* (New.).

Bānādā (बानाडा—Nep.)—A Buddhist community of craftsmen among Newaris in Nepal.

Basu miṭṭi (बसु मिट्टी—Hin.)—A type of clay gathered from the banks of tanks. *Kolli miṭṭi* (Hin.).

Belana (बेलन—Hin.)—Roller, *Mazhukuthedi* (Tam.).

Bhaṭṭhī (भट्ठी—Hin.)—Brazier, Furnace, *Ulai* (Tam.).

Bīla miṭṭi (बील मिट्टी—Ori.)—A type of clay gathered from paddy fields used in *cire perdue* casting in Orissa.

Bhūsā (भूसा—Hin.)—Chaff.

Chakkalā kāttā (चक्कला कात्ता—New.)—Round headed tool used in finishing metal images. *Chaurasiyā* (Hin.), *Deṭṭe pogarā* (Tel.).

Chatura aram (चतुर अरम्—Tam.)—Square file. *Chaukora reti* (Hin.).

Chatura metiyan (चतुर मेतियन्—Tam.)—Square headed tool used for finishing metal images. *Chaurasiyā* (Hin.), *Deṭṭe pogarā* (Tel.).

Chaukora reti (चौकोर रेती—Hin.)—Square file. *Chatura aram* (Tam.).

Chaumitiyan porai (चौमितियन् पोरै—Tam.)—Curved (light) shaping tool made of steel.

Chaurasiyā (चौरसिया—Hin.)—Square headed tool used in finishing metal images. *Chatura metiyan* (Tam.), *Deṭṭe pogarā* (Tel.).

Cheṅchilyam (चेनचिल्यम्—Mal.)—Rosin, *Kuṅgulīyam* (Tam., Mal.), *Rāla* (Hin., New.).

Chipaṭṭi reti (चिपटी रेती—Hin.)—Flat file, *Paṭṭai aram* (Tam.).

Chīuḷi (चीउली—Tam.)—Scraping chisel made of steel. *Chīvvelegā* (Tel.), *Chīvvè pogarā* (Tel.).

Chīvvelegā or *Chīvvē pogarā* (चीव्वेलेगा या चीव्वे पोगरा—Tel.)—Scraping chisel made of steel. *Chīuḷi* (Tam.).

Chūḷa koradu (चूल कोरडु—Tam.)—lifting tongs.

Chuthy (चुत्ति—Tam.)—Hammer. *Hathorī* (Hin.).

Datūrā (धतूरा—Hin.)—Thorn apple, *Hema pushpa* (Sans.).

Deṭṭe pogarā (डेट्टे पोगरा—Tel.)—Square headed tool used in finishing metal images. *Chatura metiyan* (Tam.), *Chaurasiyā* (Hin.).

Dharkrī (धक्कंरी—Raj.)—Bell metal. *Kānsi* (Raj., Punj., Kash.), *Phūl* (Hin., Punj., Kash.).

Goharī (गोहरी—Hin.)—Cowdung cakes, *Varali* (Tam., Mal.).

Gola retī (गोल रेती—Hin.)—Round file. *Uruṇḍa aram* (Tam.).

Gōla chaurasiyā (गोल चौरसिया—Hin.)—Round headed tool used for finishing metal images. *Uruṇda metiyan* (Tam.).

Gōla compass (गोल काम्पस—Hin.)—Compass.

Goniyā (गोनियां—Hin.)—Try square.

Gorū pōgarā (गोरू पोगरा—Tel.)—Diamond-pointed chisel. *Kīrtimukham* (Tam). *Āgè muhā chaurasiyā* (Hin.).

Gubbogārā (गुब्बो गारा—Tel.)—Tool used to shape breast and mamillas.

Hathorī (हथौड़ी—Hin.)—Hammer, *Chuthy* (Tam.).

Hema puṣhpa (हेम पुष्पं—Sans.)—Thorn apple, *Datūrā* (Hin.).

Hīra (हीर—Hin.)—hard pith wood. *Vairam* (Tam.).

Iḍukkī (इडुक्की—Tam.)—Long tongs or clip tongs. *Sadsī* (Hin.).

Imalī (इमली—Hin.)—Tamarind. *Pulī* (Tam., Mal.).

Jaḍu miṭṭi (जेडु मिट्टी—Tel.)—A light yellow clay used for moulding by craftsmen near Tirupathi in Andhra Pradesh.

Kadalai eṇṇai (कड़लै एण्णै—Tam.)—Groundnut oil. *Mūṅgaphali kā tèla* (Hin.).

Kadanā (कडना—Hin.)—Half round tool.

Kaiṅchī (कैंची—Hin.)—Scissors.

Kalama (कलम—Hin.)—Spatula used for modelling in wax.

Kalarpumezhuku (कलपुं मेलुगु—Tam.)—Wax compound. *Mayin* (Hin., New.).

Kaṁbitīyan (कंबितीयन्—Tam.)—Liner. *Sūttanā* (Hin.), *Rekhā pogarā* (Tel.).

Kammālar (कंम्मालर—Mal., Tam.)—Artisan class who practise carpentry, carving, metal casting, etc. *Viśvakarmā* (Sans.), *Kamsālā* (Tel.), *Pānchālā* (Can.).

Kamsālā (कम्साला—Tel.)—Artisan class who practise carpentry, carving metal casting, etc. *Viśvakarmā* (Sans.), *Kammālar* (Tam., Mal.), *Pānchālā* (Can.).

Kānsi (कान्सी—Raj., Punj., Kash.)—Bell metal, *Dharkrī* (Raj, local technical language near Siwai Madhopur, Rajasthan), *Phūl* (Hin., Punj, Kash.).

Kaṇṇu porai (कण्णु पोरैं—Tam.)—Tool used for shaping the eyes in metal images.

Kāpu porai (कापु पोरै—Tam.)—Tool used for shaping bangles.

Karū (करु—Tam.)—Mould, *Sānchā* (Hin.).

Karuvū (करुवु—Tam.)—Wax model, literal meaning fetus.

Kāsa pushpa (कास पुष्पं—Sans.)—Flower of a long stemmed grass found in India.

Kaṭhino mṛīd (कठिना मृदा—Sans.)—Hard clay.

Katti aram (कत्ति अरम्—Tam.)—Knife-edged file.

Kīrtimukham (कीर्त्ति मुखम्—Tam.)—Diamond pointed chisel, *Agé muhā chaurasiyā* (Hin.), *Goru pogarā* (Tel.).

Kiruttanam (कीरुत्तनम्—Tam.)—Sharp lozenge shaped tool used in finishing metal images.

Kocharā tèla (कोचरा तेल—Hin.)—Oil obtained from the fruits of Mahua tree *(Bassia latifolia)*.

Kolli miṭṭi (कोल्लि मिट्टी—Hin.)—A type of clay gathered from the banks of tanks for moulding by the artisans of Madhya Pradesh. *Basu miṭṭi* (Hin.).

Koluno pogarā (कोलुपो पोगरा—Tel.)—Tool used for shaping designs and garlands in metal images. *Pūporai* (Tam.).

Kshaṇikaberā (क्षणिकबेरा—Sans.)—Temporary immage.

Kuchchi aram (कुच्चि अरम्—Tam.)—Needle file.

Kunguliyam (कुङ्गलीयम्—Tam., Mal.)—Rosin. *Cheṅchilyam* (Mal.), *Rāla* (Hin., New.).

Kūvai (कूवै—Tam.)—Crucible.

Lakaḍi (लकड़ी—Hin.)—Wood.

Lakshana (लक्षणम्—Sans.)—Symbol.

Lāla miṭṭi (लाल मिट्टी—Hin.)—Red clay.

Lambapalakāy (लम्बपलकाय्—Tam.)—A board having vertical and horizontal linear divisions used by the craftsmen in *cire perdue* casting in South India.

Linga lakṣhanam (लिङ्गलक्षणम्—Sans.)—Attributes for Linga.

Maduchchhiṣṭa vidhānam (मघुच्छिष्टविधानम्—Sans.)—*Cire perdue* or lost wax process of casting.

Manda-kathinā mṛid (मन्दकठिना मृदा—Sans.)—Semi-hard clay.

Mankaṭṭāl (मणकट्टल—Tam.)—Moulding.

Maṭṭala veṭṭirimbu (मट्टल वेट्टिरुम्बु—Tam.)—Circular headed tool used for rounding off corners.

Maṭṭuḷi (मट्टुली—Tam.)—Half round chisel.

Merugu isukā (मेरुगु इसुका—Tel.)—A variety of sea sand used for polishing metal.

Mezhuku katti (मेलुकु कत्ति—Tam.)—Knife used for modelling in wax. *Patti* (Hin.).

Mezhuku kuchi (मेलुकु कुच्ची—Tam.)—Spatula used for modelling in wax. *Kalama* (Hin.).

Mezhukuthadi (मेलुकुत्तडी—Tam.)—Wooden roller used in wax modelling. *Belana* (Hin.).

Moma (मोम—Hin.)—Beeswax. *Thenmezhuku* (Tam.).

Mṛidu mṛid (नृदु मृदा—Sans.)—Soft clay.

Mṛidutarā mṛid (मृदुतरा मृदा—Sans.)—Very soft clay.

Mṛitunam (मृतुनम्—Tam.)—Smoothing or planishing tool.

Mukhattuṇi (मुखत्तुणी—Tam.)—A circular ring of rag placed around the mouth of the orifice of the pouring cup while pouring the liquefied metal inside the cavity on the mould in order to prevent the spilling of metal.

Mūṅgaphali kā tela (मूंगफली का तेल —Hin.)—Groundnut oil. *Kadalai eṇṇai* (Tam.).

Muppaṭṭai aram (मुप्पट्टै अरम्—Tam.)—Triangular file. *Tintirā reti* (Hin.).

Mūrati (मूरती—New.)—A square headed tool used for finishing images. *Chatura metiyan* (Tam.), *Chaurasiyā* (Hin.), *Dette pogarā* (Tel.).

Mushā karnā mṛid (मूषा करणा मृदा—Sans.)—Clay for making crucible.

Nagāsipokkā (नगासी पोकका—Tam.)—Engraving tool.

Nalayaya veṭṭiriṁbu (नलवाय वेट्टिरुम्बु—Tam.)—Flat chisel.

Oḍi ōlāi(ओडि ग्रोलै—Tam.)—A measuring device made from fresh cocoanut palm leaf.

Oulai kambi(उलै कम्बी—Tam.)—Skimmer.

Pānchālā(पाञ्चाला—Can.)—*Viśvakarmā* (Sans.), *Kammālar* (Tam., Mal.), *Kamslā* (Tel.).

Pañchalōhā(पञ्चलोहः—Sans.)—An alloy of five metals (copper, silver, gold, brass and white lead).

Pathikkōl(पत्तिक्कोल—Tam.)—Soldering iron.

Pattī(पत्ती—Hin.)—Steel knife made from used hacksaw blade. *Mezhuku kdṭṭi* (Tam.).

Paṭṭa miṭṭi(पट्ट मिट्टी—Tel.)—A light yellow clay used for moulding by craftsmen near Tirupathi in Andhra Pradesh. *Joḍu miṭṭi* (Tel.).

Paṭṭai aram(पट्टै ग्ररम्—Tam.)—Flat file. *Chipaṭṭi rati* (Hin.).

Phūl(फूल—Hin., Punj., Kash.)—Bell metal. *Kansī* (Raj., Punj., Kash.), *Dharkri* (Raj. local technical language near Siwai Madhopur).

Pīlī miṭṭi(पीली मिट्टी—Hin.)—Yellow clay.

Powarī(पौवारी—Hin.)—Concave tool. *Ullukku vaḷavu veṭṭirimbu* (Tam.), *Tamara pagarā* (Tel.).

Pulī(पुलि—Tam., Mal.)—Tamarind, *Imalī* (Hin.).

Pūparai(पूपोरै—Tam.)—Tool for making flower designs and garlands. *Kolupō pogarā* (Tel.).

Rāhu kālam(राहु कालम्—Tam.)—A particular time of each day which is considered inauspicious to initiate any new undertaking.

Rāla(राल—Hin.)—Rosin. *Kuṅguliyam* (Tam., Mal.), *Chañchilvam* (Mal.).

Rèkhā pogarā(रेखा पोगरा—Tel.)—Liner. *Kaṁbitīvan* (Tam.), *Sūttanā* (Hin.).

Rūi miṭṭi(रुई मिट्टी—Hin.)—A river clay of brown colour used for moulding by craftsmen in Madhya Pradesh.

Sadasi(संड़सी—Hin.)—Long tongs. *Iḍukkī* (Tam.).

Sākya(शाक्या—Sans., New.)—Royal clan to which Lord Buddha belonged; now a caste title among the artisans in Nepal.

Śānchā(सांचा—Hin.)—Mould. *Karu* (Tam.).

Śāstras(शास्त्रम्—Sans.)—Rules.

Śilpi(शिल्पी—Sans.)—An artisan who works in wood, stone or metal.

Sthapati (स्थपति—Sans.)—A sub-caste among the Viśvakarmas in South India. *Sthapathi* (Tam.).

Summa pagarā (सुम्म पोगरा—Tel.)—Tool used for inlaying stars and dots.

Sūttanā (सूतना—Hin.)—Liner. *Kaṁbitiyan* (Tam.), *Rekha* '*pagara* (Tel.).

Toimūroti (तैमूरति—New.)—Rectangular headed tool. *Vatti pogara* (Tel.), *Badama* (Hin.).

Talai aram (तलै ग्ररम्—Tam.)—Double headed file.

Tamarapogara (तांम्र पोगरा—Tem.)—Concave tool. *Uḷḷukku voḷavu veṭṭirimbu* (Tam.).

Thapī (थापी—Hin.) —Plainer. A wooden tool used while modelling in wax by craftsmen in Varanasi.

Tintira retī (तीनतीरा रेती—Hin.)—Triangular file. *Muppaṭṭai aram* (Tam.).

Thenmekzhugu(तेन मेकुगु—Tam.)—Beeswax. *Moma* (Hin.).

Udāsa (उदास—New.)—A Buddhist community of crafısmen among Newaris. *Banada* (Nep.).

Ulai (उलै—Tam.)—Forge or Furnace. *Bhaṭṭi* (Hin.).

Uḷḷukkuvaḷavu veṭṭirimbu (उल्लुकु वकवु वेट्टिरुम्बु—Tam.)—Concave chisel. *Tamaro pagara* (Tel.), *Powarī* (Hin.).

Uruṇda aram (उरुण्ड़ अरम्—Tam.)—Round file. *Gola retī* (Hin.).

Urunda metiyan (उरुण्ड़ मेतियन्—Tam.)—Round headed tool. *Gola chaurasiyā* (Hin.).

Vairam(दैरम्—Tam.)—Hard pith wood. *Hīra* (Hin.).

Vaḷavu pōrai (वलवु पोरै—Tam.)—Curved tool.

Vaḷavuuli (वलवु उली—Tam.)—Curved chisel.

Vaḷavu veṭṭirimbū (वकवु वेट्टिरुम्बु—Tam.)—Convex chisel. *Vaḷu pogara* (Tel.).

Vaḷu pogara (वलु पोगरा—Tel.)—Convex chisel. *Vaḷavu Veṭṭirimbu* (Tam.).

Varali (वरली—Tam.)—Cowdung cakes. *Goharī* (Hin.).

Vardhakī (वर्धकी—Sans.)—Sthapati's assistant.

Vatti pogara (वत्ति पोगरा—Tel.)—Rectangular headed tool. *Badama* (Hin.), *Taimūratī* (New.).

Viśvakarma (विश्वकर्मा—Sans.)—Architect god. Artisan class who practise carpantry, stone carving, gold-smith work, etc. *Kammālar* (Tam., Mal.), *Kamsala* (Tel.), *Panchālā* (Can.).

Yav (यवा—Sans.)—A unit of measurement in India.

Yō dekgō sapuō (यो डकगो सापो—New.)—An iconographic text in Newari.

GLOSSARY

Foreign Terms

Ara-tsuchi (Jap.) — Moulding clay used for third layer.

Cavity-less casting — A new process of *cire perdue* casting using foam plastic avoiding the burn out process.

Cere de cempeche (Sp.) — Beeswax.

Cire perdue (Fr.) — Lost wax process of metal casting.

Chou li (Chi.) — Part of an ancient Chinese written record of the great code belonging to Chou dynasty period.

Covering mould — mother mould, jacket.

Devesting — Knocking off the mould after casting.

Dewaxing — Melting out the wax from inside the mould.

Fan (Chi.) — Mould.

Foam plastic — Cellular plastic or expanded plastic.

Gesso — (Ita. L.) — Plaster of Paris.

Grog — Pulverized fired earth clay or pottery, fire brick or ordinary red building brick.

Grottoes — Caves.

Hydrocol — A special casting plaster which can withstand high temperature.

Investment — Moulding material used for negative mould in *cire perdue* casting.

Investment casting — Lost wax process or *cire perdue* process of casting.

Kami-tsuchi (Jap.) — (Paper clay) clay used for first layer in moulding.

Kan Kuo (Chi.) — Crucible.

Kiao Kung chi (Chi.) — A section of the Chinese written record known as *Chou li* (Chi.).

Karakane (Jap.) — Chinese metal. An alloy of copper, tin, zinc, and lead.

Kome-gata (Jap.) — A method of metal casting. *Yaki-gata* (Jap.).

Mandriani (Ita.) — A shank.

Mother mould — covering mould, jacket.

Polyvinyl rubber — A synthetic rubber prepared from polyvinyl chloride.

Precision casting — A term used in industry for lost wax of *cire perdue* casting.

Repousse (Fr.) — Relief work done on sheet metal by hammering.

Ro-gata (Jap.) — Lost wax or *cire perdue* process of casting.

Samrit (Khm.) — An alloy of nine metals gold, silver, copper, zinc, mercury, tin, iron, bismuth and lead. *Thong tu 'O'ng* (Khm.).

So-gata (Jap.) — A method of metal casting.

Tamara devarup (Khm.) — A treatise on Iconography.

Tama-tsuchi (Jap.) — Moulding clay used for the second coat in *cire perdue* casting.

Tatara (Jap.) — Bellows.

Teculatl (Azt.) — Coal water.

Thong tu 'O'ng (Khm.) — An alloy of nine metals. *Samrit* (Khm.).
Toreutike (Gr.) — Method of finishing a metal cast.
Tumbaya (Azt.) — An alloy of gold, silver and copper.
Yaki-gata (Jap.) — A method of metal casting. *Kome-gata* (Jap.).
Xona (Gr.) — A wooden carved figure.

ABBREVIATIONS

Vernacular (*Indian*)

Canarese — Can.
Hindi — Hin.
Kashmiri — Kash.
Malayalam — Mal.
Nepali — Nep.
Newari — New.
Oriya — Ori.
Punjabi — Punj.
Rajasthani — Raj.
Sanskrit — Sans.
Tamil — Tam.
Telugu — Tel.

Foreign (*other than English*)

Aztec — Azt.
Chinese — Chi.
French — Fr.
Greek — Gr.
Italian — Ita.
Japanese — Jap.
Khmer — Khm.
Latin — L.
Spanish — Sp.

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